# PROCEEDINGS
# EIGHTH GENERAL MEETING
# 1954

# THE AMERICAN SOCIETY OF SUGAR BEET TECHNOLOGISTS

---

**Volume VIII**

**Part 1**

---

**Containing papers presented in**
**Meeting, February 2-5, 1954, Denver, Colorado**

*Published by:*

**The American Society of Sugar Beet Technologists**

**Office of the Secretary**

**Fort Collins, Colorado, U.S.A.**

ROBINSON-WARFIELD PRINTING CO.
Fort Collins, Colorado
1954

# ACKNOWLEDGMENT

Cooperation of the beet sugar industry in the United States of America and the Dominion of Canada, through the Beet Sugar Development Foundation, is gratefully acknowledged. Financial assistance from this source permits the publication of the research results contained herein.

Gratitude is expressed to members and others who gave generously of their time in preparing the contents of this publication. Appreciation is expressed for the efforts of those who developed the program of the Eighth General Meeting from which the papers in this publication were compiled.

# OFFICERS, ADVISORY COUNCIL AND COMMITTEES

## 1952-1953

### OFFICERS

C. E. Cormany ..... *President*
Bion Tolman ..... *Vice President*
P. A. Reeve ..... *Immediate Past President*
J. H. Fischer ..... *Secretary-Treasurer*

### ADVISORY COUNCIL

West Coast ..... R. T. Johnson, L. D. Leach
Intermountain ..... F. N. Rawlings, Myron Stout
Eastern Slope ..... L. H. Andrews, R. H. Cotton, A. R. Downie
Eastern United States ..... M. G. Frakes, H. L. Kohls
Eastern Canada ..... B. E. Easton
Western Canada ..... F. H. Peto
At Large ..... R. J. Tingley, R. S. Gaddie

### COMMITTEES

GENERAL PROGRAM CHAIRMAN

Austin Armer

SECTION PROGRAM CHAIRMEN

F. J. Hills, Agronomy
H. L. Kohls, Genetics and Variety Improvement
Orin A. Hills, Entomology and Plant Pathology
Read A. Wilkinson. Agricultural Engineering
R. S. Gaddie, Chemistry and Factory Operation
R. H. Cotton, Physiology

CONSTITUTION AND BY-LAWS COMMITTEE

H. P. H. Johnson, Chairman
H. E. Brewbaker
C. A. Lavis
J. H. Fischer

NOMINATING COMMITTEE

A. A. Mast, Chairman
H. E. Ellison
B. E. Easton
E. J. Maynard
J. S. McFarlane

RESOLUTIONS COMMITTEE

H. E. Brewbaker, Chairman
A. M. Murphy
L. A. Kloor

GENERAL ARRANGEMENTS COMMITTEE

Holger Figge, Chairman
Reginald S. Carey
P. B. Smith
V. I. Morris
T. H. Ferril
H. P. H. Johnson

PUBLICATIONS COMMITTEE

P. B. Smith, Chairman
G. R. Larke
G. D. Manuel
J. H. Fischer

AWARDS COMMITTEE

W. Y. Cannon, Chairman
H. E. Brewbaker
P. A. Reeve

REGISTRATION

H. L. Bush

# TABLE OF CONTENTS

## GENERAL SESSIONS


| | Author | Page |
|---|---|---|
| Cooperative research | *C. E. Cormany* | 3 |
| Patterns of cooperation in sugar beet research | *Martin G. Weiss* | 7 |
| What's new in sugar research? | *H. B. Hass* | 15 |


## AGRONOMY

### FERTILITY, ROTATION AND IRRIGATION


| | Author | Page |
|---|---|---|
| Effect of method of application of double superphosphate on the yield and phosphorus uptake by sugar beets | *W. E. Larson* | 25 |
| A study of the effect of magnesium sulfate on yield and sucrose content of sugar beets | *E. M. Holst*<br>*C. E. Cormany* | 32 |
| Response of sugar beets to nitrogen fertilizer in the Imperial Valey, California | *B. A. Krantz*<br>*A. J. MacKenzie* | 36 |
| The effect of fertilizer treatments upon yield and sugar content of sugar beets at Garden City, Kansas | *Carl W. Carlson*<br>*Roy B. Herring* | 42 |
| The application of petiole analysis to sugar beet fertilization | *D. Ririe*<br>*A. Ulrich*<br>*F. J. Hills* | 48 |
| Anhydrous ammonia, the effect of time, rate and technique of its application in the production of sugar beets | *F. H. Leavitt*<br>*R. L. Stier* | 58 |
| Response of yield-type versus sugar-type sugar beet varieties to soil nitrogen legels and time of harvest | *F. J. Hills*<br>*L. M. Burtch*<br>*D. M. Holmberg*<br>*A. Ulrich* | 64 |
| Cropping and fertilization practices for the production of sugar beets in Western Nebraska | *H. F. Rhoades*<br>*Lionel Harris* | 71 |
| The fertility balance in a ten-year sugar beet rotation after forty-two years of cropping | *S. Dubetz* | 81 |
| Effects of rotation on sugar beets in the Red River Valley | *J. C. Tanner* | 86 |

## TABLE OF CONTENTS (Cont.)


| | Author | Page |
|---|---|---|
| Preliminary comparison of the effects of Leguminous and non-leguminous green manures on sugar beet production | *W. A. Williams*<br>*D. Ririe*<br>*H. L. Hall*<br>*F. J. Hills* | 90 |
| Stand and yield of sugar beets, and weed populations as affected by: broadcast fertilization, mechanical thinning, application of herbicides and their interactions | *G. J. Hogaboam*<br>*H. W. Bockstahler*<br>*Buford H. Grigsby*<br>*George W. French* | 95 |
| Irrigation and fertility studies on sugar beets at Logan, Utah | *Vaughn E. Hansen*<br>*Jay L. Haddock* | 106 |
| Sugar beet irrigation experiments in Wyoming | *W. McNab Miller*<br>*Jay R. Partridge*<br>*Carrol Tyler* | 112 |
| Progress report on irrigation experiment—Rader farm, Saginaw, Michigan | *Hal B. Reeve*<br>*Ernest H. Kidder* | 120 |
| **CHEMICAL WEED CONTROL AND SOIL CONDITIONERS** | | |
| The control of annual grasses in sugar beets with Dalapon | *L. E. Warren* | 124 |
| Grass control in sugar beets with the herbicides IPC, TCA and DCU | *R. T. Nelson* | 130 |
| Pre-emergence applications of a combination of TCA and Endothal show promise for control of grassy and broadleaf weeds in sugar beets | *C. E. Cormany* | 135 |
| Results with IPC spraying in Eastern Montana | *E. G. Eckroth* | 135 |
| The use of chemical additives to control soil crusting and increase emergence of sugar beet seedlings | *Bruce L. Baird*<br>*Joseph J. Bonnemann*<br>*Arch W. Richards* | 136 |
| Influence of Krilium soil conditioner on sugar content of beets | *C. H. Smith* | 143 |
| **MISCELLANEOUS** | | |
| Problems connected with high beet populations | *L. J. Holmes*<br>*Curzon Kay* | 147 |
| Estimate of space occupied proposed as a measure of sugar beet stands | *G. W. Deming* | 151 |

## TABLE OF CONTENTS (Cont.)


| | Author | Page |
|---|---|---|
| Cultural practices related to yields and germination of sugar beet seed | *R. A. Pendleton* | 157 |
| Comparison of hand and machine thinning of sugar beets | *Albert S. Hunter*<br>*John A. Yungen* | 161 |
| Sugar beet planting date studies in Imperial Valley, California | *Charles Price*<br>*Don C. Fife*<br>*B. A. Krantz* | 164 |
| Experiences with sugarbeet on land flooded by the sea | *H. Rietberg* | 168 |
| Sugar losses caused by frost defoliation | *F. H. Peto* | 171 |
| The influence of Maleic Hydrazide on bolting and yield of overwintered sugar beets in California | *D. Ririe*<br>*L. M. Burtch*<br>*F. J. Hills* | 176 |


### ENTOMOLOGY AND PLANT PATHOLOGY


| | | |
|---|---|---|
| Outbreaks of beet leafhoppers north and east of the permanent breeding areas | *J. R. Douglass* | 185 |
| Curly top moves east | *N. J. Giddings* | 194 |
| Relative curly-top resistance of sugar beet varieties in the seedling stage | *N. J. Giddings* | 197 |
| Beet leafhopper outlook statements | *Howard E. Dorst* | 201 |
| Chromatography as a method of attack on the problem of the chemical nature of resistance of sugar beets to curly top | *J. M. Fife* | 207 |
| Sugar beet virus yellows influences subsequent curly top infection | *N. J. Giddings* | 212 |
| Effect of virus yellows on the yield and sucrose percentage of the sugar beet at Salinas, California, in 1952 | *J. S. McFarlane*<br>*C. W. Bennett*<br>*A. S. Costa* | 215 |
| Results of an experiment in Colorado to appraise effects of virus yellows in sugar beet | *G. H. Coons*<br>*John O. Gaskill*<br>*Leslie B. Daniels* | 219 |
| Histological changes produced by virus yellows in sugar beet leaves | *C. F. Lackey* | 225 |
| Observation and studies of virus yellows of sugar beet in California | *C. W. Bennett*<br>*A. S. Costa* | 230 |

## TABLE OF CONTENTS (Cont.)


| | Author | Page |
|---|---|---|
| Effect of virus yellows on yield and sucrose content of sugar beet in tests at Riverside, California | *C. W. Bennett*<br>*Charles Price*<br>*Glenn E. Gillespie* | 236 |
| An alternaria leaf spot of the sugar beets | *J. S. McFarlane*<br>*Roy Bardin*<br>*William C. Snyder* | 241 |
| Methods of inoculating sugar beets with Aphanomyces cochlioides drechs | *C. L. Schneider* | 247 |
| Correlation between sugar beet crop losses and greenhouse determinations of soil infestation by Aphanomyces cochlioides | *H. C. Fink*<br>*W. F. Buchholtz* | 252 |
| Field trails with soil row treatment for the control of damping-off of sugar beets | *Torrey Lyons*<br>*L. D. Leach*<br>*F. J. Hills* | 260 |
| A comparison of several methods of testing sugar beet strains and individual roots for resistance to storage pathogens | *John O. Gaskill* | 264 |
| Identification of some materials in root exudates of nematode (Heterodera Schachtii, Schmidt) host plants | *R. R. Wood*<br>*R. F. Serro* | 271 |
| Endrin — a new insecticide for sugar beet webworm control | *R. E. Hamman*<br>*R. T. Nelson* | 276 |


## AGRICULTURAL ENGINEERING

### LAND PREPARATION, PLANTING AND THINNING


| | | |
|---|---|---|
| Minimum seed bed preparation | *M. G. Frakes* | 281 |
| An improved method of applying fertilizer to sugar beets | *M. G. Frakes*<br>*H. L. Draher* | 285 |
| Preventative weed control — methods and equipment | *John T. Maletic* | 291 |
| Planting for machine thinning | *L. A. Lohmeier* | 296 |
| Status of spring mechanization in the Michigan area | *M. C. Henderson* | 299 |
| Thinning trials in Eastern Montana | *E. G. Eckroth* | 302 |
| Spring mechanization in the Red River Valley—1953 | *H. A. Tvedten* | 305 |

## TABLE OF CONTENTS (Cont.)


| | Author | Page |
|---|---|---|
| Mechanical thinning of sugar beets in the area served by the Utah-Idaho Sugar Company | *Bion Tolman*<br>*Ronald C. Johnson* | 306 |
| Five years' experience in complete mechanical thinning of sugar beets | *A. M. Watson*<br>*L. H. Henderson* | 309 |
| A dynomometer for determination of the power requirements of a sugar beet thinner | *George W. French* | 313 |
| **HARVEST AND RECEIVING** | | |
| Five years' mechanical harvesting experience with completely machine thinned beets | *A. M. Watson* | 318 |
| Harvesting equipment | *George W. Nixon* | 320 |
| Influence of machine harvest on receiving facilities | *Austin Armer* | 324 |
| Relationship of screening to beet population | *L. J. Holmes*<br>*Curzon Kay* | 327 |
| Comparative efficiency of rubber and steel Rienks screens | *Charles R. Johnson* | 330 |
| End dump arrangements on old and new receiving equipment | *R. W. Brandt* | 333 |
| Beet receiving equipment | *Glen W. Yeager* | 337 |
| Improved beet sample taking with new-design pan | *Art Johnson* | 340 |
| Basic beet piler design and its application to construction | *Read A. Wilkinson*<br>*J. G. Stone* | 344 |
| Sugar beet storage problems | *L. R. Cool* | 353 |
| Adapting the Marbeet Midget beet harvester to experimental plot harvest | *R. E. Johnson* | 356 |
| Conserving and handling beet tops | *E. L. Swift* | 357 |
| **MISCELLANEOUS** | | |
| Irrigation of sugar beets | *Ivan D. Wood* | 362 |
| Equipment for beet seed treating | *L. A. Kloor* | 366 |
| Seed treating machinery | *George E. Walters* | 372 |
| Processing and testing of monogerm seed | *L. A. Kloor*<br>*George E. Walters*<br>*G. E. Rush*<br>*Charles Price*<br>*Austin Armer* | 376 |
| Field stands obtained from plantings of variously processed mono- and multi-germ sugar beet seed | *George E. Walters* | 379 |
| AUTHOR INDEX | | 383 |

# GENERAL SESSIONS

# Cooperative Research

C. E. CORMANY[1]

In this day of surpluses and quotas, mention of possible food shortages in the future may seem out of place, but it is of these possible shortages and how we may avoid them that I wish to say a few words—and especially as it applies to sugar.

As a group we are vitally interested in the future food supply, not only of this country but of the entire world. We feel that, in order to be happy and perform out duties as good citizens, we must eat well. We all know the seriousness of a short food supply as experienced in many foreign countries.

Let us for a few minutes review the food picture—*viz.* human food—as it is today and as it may be two or three decades hence.

Little need be said about today's food supply except that we seem to be living in an era of surplus in foods and farm products in America. Will it always be thus?

Even now, in a time of abundance, we all too frequently hear about the "Fifth Plate" that will be necessary in order to feed our growing population by 1975. The demand for human food is growing each year. During the last few years our population has increased at the astounding rate of some 2,800 to 3,000 per day, and probably will continue to do so. During the two-hour session here this afternoon there will have been born in the United States some six hundred new Americans, or about five every minute. These newcomers must be fed, and fed well, to maintain our present standard of living.

Our overall position has been well summarized in an article in the Agronomy Journal of March, 1953, by Byron T. Shaw, Administrator of Agricultural Research, U. S. Department of Agriculture. He points out the following facts:

1. "Our population will continue to increase.
2. "We do not want any deterioration in the American diet.
3. "We need to increase agricultural products, make better utilization of the products produced and improve distribution.
4. "The expected increase in cropland by 1975 will provide only a small part of the projected increase in production that will be needed.
5. "Substantial improvements in current agricultural technology will be required if the nation's needs for agricultural products in 1975 are met."

It is evident that our population is rapidly increasing. Look about you and observe the new homes, new schoolhouses and new churches that are being built. In 1952 there were 920,000 new households established. The Bureau of Census estimates our 1975 population at 190,000,000; others estimate it well over 200,000,000. Our food needs at that time will be at least one-third more than they were fifteen years ago.

---

[1]President, American Society of Sugar Beet Technologists, 1952-53; chief agronomist, Holly Sugar Corporation. Address given at biennial meeting of Society, February, 1954.

In the past twenty-five years crop yields in the United States have increased more than 40 percent and livestock products more than 20 percent. Much of this increase has been made during the last fifteen years. It indicates that the use of new methods of farming, new fertilizer and irrigation practices, and improved varieties are being rapidly adopted and used by our farmers. In many cases they are beginning to catch up with the research phase of our agriculture and are closing the lag or gap between research and its application.

Better utilization is being made of all crops now as compared to two decades ago. We don't have to go any farther away than the lowly sugar beet to see this. It is manifest in better use of the byproducts, both from the factory and the field. Similar advances, and some even more spectacular, have been made in the utilization of other major crops.

Something is being done about the better distribution of our food products. Many new and novel ways of handling have been developed. Only last year a new method of handling lettuce was introduced. New packaging and methods of selling sugar have appeared in recent years.

The experts in the Bureau of Agricultural Economics, and others, conclude that it may be possible to add from 25,000,000 to 35,000,000 acres to our crop land by 1975. This would be done largely by new irrigation or reclamation projects and some pasture land. The application of atomic energy for the use in transportation of irrigation water may be a big factor in developing new crop land.

But this acreage is not enough. Simple arithmetic shows that it will take more acres to meet our needs at the 1950 yield rates. Much of the new land which could be made available for crop production borders on the "marginal type." Economically it is not attractive in that this land will not yield a satisfactory return on the required investment. It simply means that we will have to increase the per acre production of all crops.

Again, the experts feel that exports and imports of food will make little difference in the overall picture. New foods from the ocean, as well as new synthetics, no doubt, will help some—maybe more than we can possibly visualize at present.

How does the sugar beet fit into this overall picture? Does it have an important place in the feeding of our future population? Yes, it certainly does. Of the total world consumption, foods derived from the cereals make up about 75 percent, fruits and vegetables 10 percent, animal products about 10 percent, and sugar 5 percent.

How about here in the United States? Here the consumption is somewhat lower for foods from grain derivatives and about twice as high for animal products and sugar. This makes our product, sugar, of major concern for the future. And well it may be since its uses are so widespread in the canning, beverage and general foods industries. As the population increases, this demand for sugar will also increase. The sugar beet fields of America supply a sizable portion of our domestically consumed sugar. We must, and can, increase the sugar per acre production for sugar beets.

There is an answer to this challenge for more food which confronts us. The agricultural forces of America will meet it. They are meeting it. This group here today will be playing a part in this great project.

What is the answer? How can we maintain and increase our food supply? Can we increase our output of beet sugar?

Research and still more research is the only answer. This is being stressed by big business on all sides. Organizations such as Du Pont, the oil industries, and many others are spending millions of dollars annually to develop foods and other products. In our own industry, are production and processing methods improving as fast as they should? Are we stressing our research programs enough? Does management realize the continuing need for research? These are weighty questions. Research in the sugar beet field has scored heavily already in victories over the curly top disease, storage problems and factory problems such as the continuous battery and quality of sugar. This is no time to relax when we have to face such formidable foes as the sugar beet nematode, low purities, shrinkage losses, fuel savings, reburning of lime and the handling of sugar, both bulk and liquid.

What is research anyway? Most of us here today consider ourselves to be research men. Ask yourself the question. The answers will be many. I like the definition of Charles Franklin Kettering of Delco fame, which is as follows: "Research is an organized method of finding out what you are going to do when you can't keep on doing what you are doing now."

The sugar beet industry has made an important discovery—namely, that we cannot keep on doing what we are doing now and expect to keep a healthy business.

In accord with Kettering's definition of research, the sugar beet industry has organized to determine what we are going to do next. The U. S. Department of Agriculture, Division of Sugar Plants, and several state experiment stations have had no small part in this program, and the sugar companies have done a wonderful job. Our problems are many and varied, both from the standpoint of the producer and the processor. We must, above all, develop better methods of growing, handling and processing, and new varieties of better all-around quality in order to maintain the industry on a continuing paying basis. With newer methods of production and processing, all at a more economical rate, there is now a potential in America for greatly increasing the present beet sugar production.

Many of our problems are too big for any one individual or group to solve and are being tackled cooperatively.

This fact has been recognized by our scientific men—the men here today. A plant breeder in one of our leading sugar companies recently made the statement that the inbreeding program with the hybrid outlet was too big a problem for any one company or organization to solve, no matter how big their research department might be. Such a statement would have been shocking twenty years ago. It shows we are in a cooperative era, and cooperation generally pays off. A very typical example of this cooperative spirit amongst research groups is exemplified by the cooperative inbred

project. This project is entered into by all plant breeding units in this country—industry, state and national organizations, as well as related business interests—each contributing a part of the material to be tested and each unit doing part of the indexing. It is a fine piece of cooperation.

Don't overlook what cooperation has done to establish mechanization of the sugar beet crop in America. Cooperative efforts have helped in developing improved processing techniques now in use in our factories.

There is closer cooperation between the producing and the processing sides of the industry. Meetings of representatives from each group are helping to determine what type of research is most needed, so that first things can come first.

A quarter of a century ago there was not the free discussion between technical men of the various companies that is the practice today. This was especially true of those men concerned with the technical phases of agriculture such as plant breeding, variety testing and kindred subjects.

What has brought about this change? What has been responsible for the more liberal viewpoint of today? I want to claim, on behalf of our Society, that the American Society of Sugar Beet Technologists has been largely responsible for this spirit of cooperation and advance. The formation of this Society marked the beginning of a new era so far as interchange of ideas was concerned. At our meetings, barriers of prejudice have been broken down and many friendships formed which have meant a stepped up production in many ways. Speaking from the viewpoint of one who has been connected with the breeding phase of sugar beet improvement, I can truthfully say that the last few years have seen much more free exchange of ideas and material than was at one time ever expected to occur. The same holds true in the other fields of research connected with the industry. Part of this development and progress, for progress it is, has been due to the fact that our Society has afforded a common meeting place for men interested in similar phases of endeavor. The Beet Sugar Development Foundation has also been a great factor during the last ten years in promoting cooperative efforts.

As a Society we have grown into full-fledged youth—a vigorous organization anxious and willing to take on its responsibilities in the field in which it operates.

Fellow members, our Society has done much for the industry as a whole. There is a continuing need for its functions. Let's keep the good work going and the sugar bowl full for future generations.

# Patterns of Cooperation In Sugar Beet Research

MARTIN G. WEISS[1]

Those of us in the federal-state network of agricultural research are well aware of the contribution of the sugar beet industry to the nation's wealth. It has been outstanding. It has increased the production of sugar in the United States by an average of 1.6 million tons annually. It insures a supply of an essential food in times of national emergency. It provides a stable market for the output of some 700,000 acres of farm land. And it adds around 300 million dollars each year to the farm income.

I believe it is fair to say that the technology which now characterizes this vigorous industry has been brought about by teamwork. It is the product of cooperation between the growers, private industry and public research.

Each member of the team has made important contributions. These began years ago under the leadership of the great chemist, Harvey W. Wiley, in studies by state experiment stations and industry to determine areas in the United States where the crop could be grown.

Scientists in public research, both the state agricultural experiment stations and the Department of Agriculture, can point with pride to their work in devising economic methods for the production of sugar beet seed in this country. They took the leadership in developing varieties with resistance to curly top, leaf spot and other diseases which have threatened the crop.

Industry has made spectacular advances in the improvement of machinery for thinning and harvesting the crop.

The close working relationships between the growers and processors have helped to encourage the use of improved production practices at every step along the line.

Looking back over the past 15 years, we can see many striking returns from the joint efforts. There has been a steady flow of new varieties. Each has represented superiority in disease resistance and other characters over the variety it was developed to replace. There have been dramatic improvements in the designs of machinery for thinning and harvesting of beets. The man hours required to produce a ton of beets have been reduced by half, from 7.5 in 1940 to less than 3.9 in 1950. A great deal of information has been compiled on the fertilizer and moisture requirements of the crops. This has made it possible to devise more effective methods for applying nutrient elements and irrigation. These improvements have been reflected by an increase in average yields of 26 percent.

The rate at which new techniques have been perfected has increased notably in the past decade. The stepped up tempo reflects a number of influences. One of these, of course, is the general advance of agricultural

[1] Chief of Field Crops Research Branch, United States Department of Agriculture, Washington, D. C.

science. New concepts, techniques and materials developed in fundamental research have been applied to problems in sugar beet production. One place we see this is in the use of new chemicals to control weeds.

Another influence of considerable importance, it seems to me, is that of organization. Modern research depends upon some unifying force to promote the rapid exchange of ideas. These can be made productive only when they are pooled and studied by scientists and engineers of many specialties. A strong organization facilitates the interchange of ideas. It promotes the development of new techniques. It hastens the correction of concepts which are in error. And it reduces the time lag between the perfection of a technique in the laboratory, its testing in the field, and its widespread acceptance by growers.

For this reason the American Society of Sugar Beet Technologists and similar groups can take a good measure of credit for the gains which have recently been made in the improvement of sugar beet production.

In these biennial sessions you have an opportunity to learn in considerable detail the progress of work along many highly specialized lines. The comprehensive program makes it possible for you to get a good idea of how the results from the various investigations may be fitted together for use on the farm or in the factory. The meetings and discussions stimulate new ideas.

Another organizational approach to crop improvement was established through the Research and Marketing Act of 1946. Under this legislation industry-wide advisory committees were set up to assist public research workers in evaluating work in progress and planning new research. It has proved an excellent measure for keeping those of us in government informed of your problems and thereby helping us to reshape research plans to gear them to the needs of the growers. It is generally agreed, I believe, that the advisory committee system also has given those of you in industry a better understanding of public research problems.

The Beet Sugar Development Foundation also has facilitated cooperation between private industry and public research.

In public research we are charged with developing new materials and methods for improving crop production. But our responsibility does not end there. We also have the task of seeing that these advances get to the farmer in the shortest possible time. Long experience has shown that this obligation can be met most effectively when public research has the backing and close cooperation of the industry concerned.

In public research we find it much easier to develop cooperative programs with an industry when there is an over-all group which can speak for all or nearly all of the participating companies. In setting up the Beet Sugar Development Foundation as a nonprofit organization to sponsor research and education programs, the industry has also provided an important link with public research.

One of the notable developments in our joint activities is a memorandum which applies to sugar beet improvement on a national scale. Here-

tofore the cooperative efforts were planned for growers east of the Continental Divide under one agreement and for those in the west under another. But the broad objectives are the same for all parts of the country. The work is governed by the same policies. And so the arrangement, nationwide in scope, marks a step forward in our cooperative relationships. This agreement is new. It was signed in February, 1953, but it is a sound basis for our joint effort.

Patterns of cooperation like other aspects of research must continually be reexamined. They must be studied in the light of new findings and the appearance of new problems. And they must be revised to fit changing conditions.

That is what has been done in revamping the cooperative program for the improvement of sugar beets. The objectives stated in the agreement make this quite clear.

The first objective covers genetic investigations toward the isolation of genes which may be used in breeding superior strains and varieties. And under the new plan attention will be given to hybrid vigor, disease resistance, monogermness of the seedballs, nematode resistance, seedling vigor, superior biochemical attributes, and high keeping quality in storage.

The second objective is to establish means whereby new genetic material resulting from these studies may be brought into widespread use by breeders and growers. As soon as evaluation tests demonstrate the merits of this material it must be distributed promptly, efficiently and at reasonable cost.

The Beet Suagr Development Foundation is taking leadership in carrying out this part of the understanding. The Foundation also has accepted the responsibility for the production of adequate supplies of elite and stock seed of new varieties.

## The Genetic Approach

You will notice that hybrid vigor heads the list of objectives in the new memorandum of understanding for sugar beet improvement. But hybrid vigor is not an isolated quality. Its value is realized when it is combined with other characters which are of special concern in sugar beet production.

Growers want monogerm hybrids which are resistant to leaf spot, black root, curly top, virus yellows and other diseases. In much of the west and particularly in California they need sugar beet hybrids with high resistance to nematode injury. Vigorous hybrids will be of greater interest to both the growers and the processors if they keep well in storage and are characterized by a high sugar content.

In other words, the plant breeders have a many-sided task in producing the hybrids needed to serve growers most effectively.

At Salt Lake City Dr. F. V. Owen has developed an ingenious technique for producing 100 percent hybrid sugar beets. He deals with two forms of

male sterility—Mendelian and cytoplasmic. With these forms he has accomplished genetically in sugar beets what the corn breeder has to do mechanically in the laborious detasseling of corn plants to furnish seed ears for corn hybrids.

In the 12 years since male sterility was discovered in sugar beets the scientists in this research have built up valuable stores of fundamental knowledge and plant material. They have a fairly good understanding of the character and how it can be used. They are mastering the knowhow for developing and maintaining male sterile lines. They now are selecting promising breeding material for use with the male steriles. They have developed a number of inbreds. These are being indexed and evaluated.

In association with Dr. Owen, Drs. V. F. and Helen Savitsky are concentrating on the incorporation of the monogerm character into basic breeding stocks in addition to many other lines of genetic research on beets. Their work is supported by funds contributed by the Beet Sugar Development Foundation. This is a particularly excellent example of close cooperation between industrial and public support of research.

In the east, Dewey Stewart and his coworkers have made encouraging progress in the development of monogerm hybrids with considerable resistance to black root rot and leaf spot. A new technique devised this past year for making crosses with a wild species appears highly promising as a means of tapping new sources of resistance to these and other diseases.

In the west, Dr. C. W. Bennett and the men associated with him have done an outstanding job in their studies on the nature of curly top and the variation in virulence of the numerous strains of this virus.

We believe that all this work in sugar beet improvement has reached a stage where it can be strengthened greatly by certain additional research. This past year at the request of leaders among sugar beet growers and in the industry, Congress appropriated funds which have enabled the Department of Agriculture to add two geneticists to the staff of sugar beet breeders.

We have been fortunate in obtaining the services of two outstanding scientists—Dr. Leroy Powers, principal plant geneticist of the U. S. Horticultural Field Station at Cheyenne, Wyo., and Dr. H. M. Tysdal, principal geneticist for the Department of Agriculture on guayule and other domestic rubber plants at Salinas, Calif.

Many of you know Dr. Powers and Dr. Tysdal. They will have an opportunity to become widely acquainted with sugar beet technologists in coming months as they visit the different areas of production. They plan to spend the next few months in detailed conferences with research men in the industry and at the state experiment stations.

Dr. Powers will make his headquarters at Fort Collins where he will work in close cooperation with the Colorado Experiment Station at Colorado A & M College. The increase in Department funds for sugar beet investigations this year is making it possible to set up a new greenhouse for the expanded program of work there.

Dr. Tysdal will continue to make his headquarters at Salinas. When it became necessary to move the work from Riverside, we took advantage of an opportunity to make use of the laboratories and field plots formerly used by the Department for guayule. These have now been reassigned to sugar beet research. We believe the relocation of the virus studies at Salinas will be helpful in cooperative studies with the California Experiment Station at Davis. The men there will assume the major responsibility for the research on cultural and agronomic problems and on mechanization to round out a well balanced cooperative program for that production area.

### Other Aspects of the Disease Picture

The virus studies, which now will be centered at Salinas, are being expanded to include work on virus yellows. Although cooperative research in the United States to determine the damage from virus yellows was begun only two years ago, Dr. George H. Coons and his coworkers have found that the disease is widespread and a potential threat to the industry. We are still not certain of the extent of loss from the disease but it appears to be a serious threat to sugar beet production in certain parts of the country, notably California.

The evidence indicates that all of our presently grown commercial varieties of sugar beets are highly susceptible to virus yellows. But a few inbred lines appear to be resistant to the strains of virus present in the United States. In the preliminary tests these inbreds have shown evidence of being noticeably less affected by virus yellows than the commercial sorts. The situation may be like the one when the first faint evidences of curly top resistance were found in sugar beets.

The next step is to determine the genetic character of this resistance, to build up breeders' strains of those isolates which may confer yellows resistance, and to find ways to incorporate the resistant genes into hybrids. The road may be a long one. We believe we should move forward on it with all the facilities at our command.

Another matter of concern is that the curly top problem is still with us, as evidenced by the outbreaks in eastern Colorado and western Kansas. This means a new job for the curly top resistance breeding program.

Still another problem area to which we are giving increased attention is that of nematodes. Interest in these minute soilborne organisms is intense. They are causing enormous losses not only in sugar beets but in many other of our major crops.

Recent research demonstrates that plants suffer from the simultaneous attacks of different types of nematodes. It is not always easy to determine which of the attackers is most serious. The presence of mixed populations of nematodes in a field makes it difficult to set up control by rotation. A certain rotation crop suitable to reduce one species may provide a host for one or more of the others. It may therefore help to increase the other pests.

Another approach which holds considerable promise is that of breeding lines of sugar beets with resistance to various species of nematodes. This approach is being used effectively in other crops.

For example, lespedeza breeders in the southeast were able to transfer resistance to two species of nematodes to the highly productive new variety, Rowan.

Cotton breeders have recently discovered resistance to root knot nematode in certain primitive or wild types. They have established a close relationship between nematode damage and susceptibility to Fusarium wilt. A few of the varieties with resistance to Fusarium wilt show a high degree of tolerance to nematodes.

Sugar beet breeders are now screening wild species of the genus *Beta* for gene sources with resistance to various species of nematodes. They have found resistance in *Beta patellaris* to the sugar beet nematode. The search will be continued and we plan to intensify our efforts to transfer the resistance to commercial sugar beet lines.

We are moving forward on many fronts simultaneously. As we are all aware, the objectives of sugar beet improvement are not limited to disease resistance, increased yields, enhancement of quality. These are important. But if the grower is to realize the benefits of these and other improvements they must be associated with characters which will aid in mechanization of the crop.

The plant breeders have made progress along this line. They have developed varieties with roots which are smoother and rounder and which lend themselves to machine harvest. They have developed varieties with greater resistance to rot following machine harvest.

We realize that the long step toward mechanization will be made when seed for vigorous monogerm hybrids can be furnished growers. Meanwhile the research on machinery for thinning and weeding the crop is moving ahead. The results of this work have been of special value in suggesting designs which may be incorporated into commercial models and in stimulating further studies.

As the supply of farm labor is reduced we must develop machines and tools which can be handled by the fewest possible workers. We must perfect still further the harvesting and handling equipment, which has already done so much to reduce the hours of arduous labor required to produce an acre of sugar beets.

The control of weeds continues to be one of the main obstacles to mechanization. Research to find chemical controls may hold the key to this problem.

One of the chief objectives is to find selective chemicals by which wild oats and broadleaved species in the sugar beet crop may be controlled economically. In Minnesota, TCA applied as a pre-emergence spray is exceedingly effective, particularly with pigeon grass and foxtail.

Some of you are familiar with the studies in which we are evaluating compounds of potential use as herbicides. In the past three years more than 400 compounds have been studied for the control of weeds in 30 different

crops. The research has begun to pay off in knowledge that certain of the compounds have high toxicity to weeds and are remarkably selective in their activity.

It seemed advisable to concentrate federal-state resources on one group of compounds at a time. This permits intensive study of specific groups of compounds known to possess herbicidal properties.

The first evaluation studies have been conducted with the carbamates because the action on plants is generally converse to that of the phenoxy compounds. The type of selectivity exhibited by the carbamates is greatly needed for weed control in sugar beets, cotton, soybeans, peanuts, and lima beans and other legumes.

When the Department of Agriculture was reorganized a few months ago, the research on the control of insects in crop plants was combined with other work and crop improvement and production. This is making it possible to tie the studies on the control of insects of special concern in a crop more closely with the research on other phases of production.

## Soil Fertility

While sugar beet growers are steadily increasing the consumption of fertilizer, it is regrettable that some farmers still apply the nutrients so sparingly that little or no benefit is obtained.

In crops and soils research we are keenly aware of the need to give greater precision to our recommendations. But much work is required before this can be done.

Increased efficiency depends upon a number of factors. This has been demonstrated quite strikingly in the Great Basin by Dr. Jay L. Haddock and the men working with him. They have found that sugar beets have a yield potential of more than 20 tons per acre when good cultural practices are combined with a recommended program of fertilization and irrigation. The highest yields were obtained when the sugar beets were planted in rows 20 to 22 inches apart and thinned to leave plants 10 to 15 inches apart in the row; from 60 to 100 pounds of nitrogen per acre were applied; and irrigations were light and frequent.

We recognize the need for a better understanding of the influence of nitrogen—both the rate and time of application—on sugar beet quality.

There is no standard procedure for appraising the nitrogen-supplying power of soils in this area. Until this procedure is devised, recommendations for applying nitrogen can be only rough approximations.

Within the past year a technique has been perfected for measuring phosphate fertility on a wide range of soils. It is a comparatively simple test which uses ordinary baking soda as the phosphate solvent.

The new test was developed in public research by Dr. Sterling R. Olsen and a group of coworkers at the Colorado Agricultural Experiment Station. It is a product of the vigorous research which was begun shortly after the

war when radioactive phosphorus became available in sufficient amounts for field experiments. With this new tool the soil scientists have gained a large store of information about the role of phosphorus in the growth of major crop plants. One of the important gains is a technique for calibrating tests for phosphorus fertility. Dr. Olsen and his colleagues used this calibration to determine the accuracy of the baking soda test.

The new test is of special interest to the sugar beet industry in the west. It offers the first dependable measure of avilable phosphorus in calcareous soils. It provides a basis for predicting yield responses from specific applications of phosphorus.

And this is the kind of information we need all along the crop production line. In agriculture we are engaged in a gigantic task of synthesis, of bringing together our scientific advances. For the sugar beet it may well begin in the breeders' plans for vigorous, monogerm hybrids which are adapted to definite areas of production, which are suitable for mechanization, which are efficient feeders on plant nutrients, which carry high resistance to diseases and insects and other crop pests of the area, and which give high yields of beets with high sugar content and good keeping quality.

We need to put under review all of our current information for every step in production practices—in seedbed preparation, planting techniques, cultivation, the application of fertilizers—and irrigation procedures to see that these are abreast of the tide of research development. We need to augment our knowledge on the effectiveness of chemicals to control weeds, plant diseases and insects in the sugar beet crop. We need a better understanding of the role of crop rotation in stabilizing sugar beet production, and in building a sound soil fertility program.

This audience is well aware that there is a research job ahead. This work must be done if sugar beet growers are to take full advantage of the gains that have come in the recent past. Much additional work will be required to perfect the new materials, machines, and techniques which now hold great promise. And all of these improvements are essential if the grower is to have a stable crop that he can produce efficiently and at a reasonable profit.

There is so much work to be done that there can be no question about whether it should be done by private industry or public research. But of this we are sure. In the future as in the past, our best and fastest progress along the road to improvement of sugar beet production will be made through the joint efforts of all the individuals and organizations concerned with this important agricultural crop.

# What's New in Sugar Research?

H. B. Hass[1]

Friends in the sugar industry: Being in Denver brings back many memories of happy vacations during which Long's Peak was climbed five times. It is pleasant to be here and to talk about your Research Foundation and what it is accomplishing.

As you know, I have been with the Sugar Research Foundation for a little over a year and a half. During this time we have had the advice and counsel of many members of both the cane and beet sugar industries. It is difficult for most members of the beet sugar industry to attend our meetings, which are usually held in New York. Therefore I welcome this opportunity to get better acquainted.

The present policy of the Foundation involves a simple concept: it is to remember to ask the question regarding any proposed research project, "If successful, what value will it have for the sugar industry?" This has annoyed a few scientists but it has saved a great deal of money and concentrated our efforts on subjects of real, potential value.

As examples of the kind of research which we have not done, I should like to mention just two projects. One was to determine the last details of the structure of galactinol, a carbohydrate found in sugar beets by Brown and Serro of Great Western. Emotionally I would have liked to do it; financially I could not justify it and the beet sugar men on our Industry Advisory Committee voted against it. The job was done anyhow on O.P.M. (other peoples' money).[2]

1953 saw the first chemical synthesis of sucrose. I am glad that this has been done. Now it is not necessary to write any more letters explaining why I am not willing to use Foundation funds for accomplishing this. We all honor Ray Lemieux for this achievement. In carbohydrate chemistry, it was equivalent to climbing Mt. Everest. Many of the greatest chemists had tried to synthesize sucrose and failed just as Leigh-Mallory, Smythe and the other Everesters had tried and failed. The probability that this sucrose synthesis will be of any practical importance to the sugar industry within our lifetime is about the same as the probability that Mt. Everest will be divided into building lots and sold.

The past year has seen the completion of two research projects of great present value to the sugar industry and five more of great potential value. Let's look at them in turn. Five are in the Foundation and two are outside.

First, let's consider the work of Ray Bohn and Foster D. Snell on the value of sucrose vs. dextrose in bread. This was completed by July 1st of 1952, but the results were so lopsidedly favorable to sugar that men in our industry refused to believe them. We had the experiments done over again in other laboratories—Arthur D. Little and the American Institute of Baking —and the facts still emerged the same.

---

[1] President, Sugar Research Foundation, Inc., New York, N. Y.
[2] This proposal did not come from either Brown or Serro.

Briefly the picture is as follows: The sugar is inverted to glucose and fructose by the invertase of the yeast before mixing the dough is even finished. Glucose is selectively fermented, leaving a disproportionate amount of fructose. The relative sweetnesses are glucose 70, sugar 100, fructose 170. Customers prefer the flavor of sweet bread and because of this the sugar in bread, based on flour, has gone from 4 percent in 1945 to 8 percent in 1953. We made the comparison in two ways. At equal cost 6 percent sugar gave sweeter bread than 7 percent dextrose. At equal sweetness 5 percent sugar was cheaper than 8 percent dextrose.

Ray Bohn and I went to the largest bread producer and talked to their chief chemist. He said, "I know you are right. I proved it in my own laboratory."

I said, "Why do you use dextrose?"

He said, "Because I was never able to sell Production on the idea. Let's call them in and see what they say."

We went through the same story with their top production men and ended it with the same question, "Why do you use dextrose?"

After a few moments of silence one of them replied, "I'll tell you why we use dextrose. We believed the advertisements of the corn products industry which said that you could substitute dextrose for sucrose pound for pound in bread and nobody could tell the difference. We thought we were saving a lot of money for our company. If what you say is true and you can prove it, no one should use dextrose in bread."

Two weeks later they threw out the dextrose.

Sugar Information has held baking schools for sugar salesmen in San Francisco, Chicago, New York and New Orleans. This year Ray Bohn is carrying this message to bakers all over America. Sugar has lost $36 million in annual business to dextrose in the baking industry. We are getting a lot of that back. When the big companies with research laboratories return to sugar, the little ones are apt to come along, too.

The second job which I want to discuss is sugar in pig-starter ration. It began in August, 1952, and was using sugar by the multiple carloads in February, 1953. The project originated in the mind of a former student of mine, Prof. Damon Catron, who is in charge of research in swine nutrition at Iowa State College. He had wrestled for years with the question of how you could get young pigs, starting at about one week of age, to eat more synthetic ration. There were many advantages if the pig-headed little fellows could only be convinced:

1. The mother sow would not step on them or smother them.

2. Sow's milk is deficient in copper and iron, resulting in partial nutritional anemia for the pigs; this could be corrected.

3. After the pigs are three weeks old the sow's milk declines in quantity while the growing pigs require more.

4. The number of filling stations on the sow is limited so that

runts were inevitable with large litters if the pigs had only sow's milk. With a synthetic ration, the geneticists could breed for large litters which reduce overhead costs.

5. The pigs could keep healthy by eating antibiotics.

6. The sow could be bred more frequently if the pigs are fed artificially, thus reducing overhead further. It might also make life more interesting for the sow.

The problem was to make the synthetic ration more palatable to the pigs. Pelletizing or granulating to eliminate dust from the feed helped, but it was not enough. Catron was listening to the radio one day when sugar-coated cereal was being advertised. Would pigs have a sweet tooth as young humans do? He asked C. & H. to support the work, and they referred him to the Foundation.

Results came rapidly. Pigs first indicated a preference for sugar-coated pellets over those with sugar mixed all the way through. After a while, however, the clever little animals learned to suck off the sugar and spit out the rest of the pellet so now results are better with uncoated pellets containing fifteen or twenty percent sugar. I often wish that food faddists had as much appreciation of sugar as pigs do.

Feed men were alert to go after a market which they never had before. They adopted it rapidly. Some, not quite so bright, are using dextrose in spite of the fact that dextrose gives less sweetness than sucrose per dollar spent. Before long we hope to have results indicating that pigs are smarter in some ways than the victims of dextrose salesmen.

The results can be expressed in two ratios. The average pig used to weigh 27 pounds at seven weeks of age; now, with the sugar ration many litters have averaged 67 pounds at the same age. This is important because feed efficiency is greater when the pigs are young. It takes only 1.7 pounds of feed to produce a pound of gain with the new ration. Fifteen years ago the over-all figure to marketable weight was five pounds of feed per pound of gain. The best comparable figure now is just under three. This is why greatest economy is obtained by inducing the young pigs to gorge themselves.

The third discovery of prime importance to us is ammoniated beet pulp, which has been known for about eleven years but which has not looked practical till just recently. The difficulty was that the Millar process for ammoniating beet pulp used elevated temperatures and pressures. The problems involved in getting dried beet pulp in and out of a pressure zone and controlling its temperature while it reacts with ammonia did not appear simple.

Now we know that neither heat nor pressure is necessary to make beet pulp react with ammonia and develop a protein equivalency (N x 6.25) or 22 percent or roughly half that of soya bean meal. It looks as if all you need is a gas-tight container, a tank of ammonia, and a valve which you can regulate.

There was, of course, a question as to whether the beet pulp ammoniated by the new technic would work satisfactorily with the rumen bacteria.

It is these microorganisms which have to be kept vigorous, for they take the simple amide structures and convert them to protein, which the cattle then turn into beefsteak and milk casein.

Just last week the word came from Cornell where tests were run at our request in an artificial rumen. The bacteria not only thrived but they dissolved fifty percent more cellulose than the controls run on ordinary beet pulp in the presence of ammonium salts.

Much work remains to be done with feeding tests. On Monday of this week members of the Industry Advisory Committee met and discussed with me just where these tests should be run. If they are successful, as we hope, a great step forward will be taken in supplying protein equivalent to the feed industry of the west and middle west. The implications are also important for countries such as Great Britain and Germany, where acreage is limited and population dense.

Dr. M. M. Rosenberg of the University of Hawaii has recently discovered that as much as 28.6 percent of cane blackstrap molasses may be added to poultry ration with good results. Under Hawaiian conditions, a saving of 7 cents is obtained in feed cost per dozen eggs. This is in striking contrast to statements in the previous literature which indicated that 3-6 percent molasses is all that chickens will tolerate. Work needs to be done with beet molasses also. It is estimated that 29,500,000 tons of poultry feed will be made and used in the United States this year. If anything like 20 percent of molasses were used in this, the molasses supply would be hopelessly inadequate. Here is a large new outlet for molasses which is just coming over the horizon.

Discovery number four is anti-enzyme tooth paste which is reported to be capable of protecting normal teeth against caries for about 12 to 16 hours. There has been so much ballyhoo about ammoniated and chlorophyll dentifrices that it would be easy to dismiss this as another variety of the same old game of bunkum. This might be a mistake. Clinical data, some of which have been published and some of which will soon appear, indicate that the anti-enzymes may be the most important discovery in the history of tooth decay.

They act by inhibiting the action of the enzymes which convert imple sugars into lactic acid. Lactic acid, if allowed to remain in contact with a tooth, will dissolve it. We in the sugar industry have been reluctant to accept the sugar-lactic acid theory of tooth decay, which makes a villain of our favorite compound. If the results continue to be as favorable as they are at present, the caries rate will be reduced some 80 percent and we can no longer continue to oppose the sugar-lactic acid theory.

Fortunately for us, it seems likely that if Dr. Fosdick proves this theory he will also be taking the heat off of us. It will be possible to eat sticky candy all day and still develop no caries.

All this is, of course, based on the assumption that present indications are substantiated. If the anti-enzymes do not stop tooth decay, this will

constitute a major failure of the sugar-lactic acid theory and will tend to discredit it. In either case the sugar industry will benefit.

If the anti-enzyme dentifrices are as successful as present data indicate, all of the manufacturers of competitive brands will be forced into a race for an even better enzyme inhibitor. There is little doubt that such a product will in time be discovered and caries will become still less important. We are supporting research at Tufts with this objective. Many compounds have already been discovered which look better than present anti-enzymes on a preliminary screening test.

The Roper survey showed that there are three tangible reasons why people do not use sugar: fear of obesity, fear of caries and fear of diabetes. Every doctor now knows that sugar does not cause diabetes; this fact is slowly diffusing to the laymen. If the anti-enzymes perform as expected against caries, it will enable us to concentrate on other problems of the sugar industry.

Fear of obesity is undoubtedly the greatest single deterrent to sugar consumption. This is understandable; the principal nutritional function of sugar is to furnish calories and calories are what the obese person is trying to minimize. The Metropolitan Life Insurance Company has repeatedly emphasized the decrease in life expectancy which overweight or obese persons show as a group. It is characteristic of Americans not to be satisfied with any method of doing anything which is slow, laborious, and unpleasant. Science has given us so many short cuts and labor-saving devices that it is easy for the general public to believe that coal-tar sweeteners provide a painless method of dieting.

I suspected that this was not true. The theory of hunger developed by Jean Mayer in Fredrick Stare's laboratory at Harvard is that the desire for food in normal, non-diabetic pesons is detemined by the level of blood sugar. It predicted that sweeteners derived from coal tar such as saccharin and Sucaryl, which would be expected not to affect the blood-sugar level, would also not affect the appetite. Experiments with rats have confirmed this conclusion. Two matched groups of rats were each given all the dry food and all the water they wanted. The water of one group contained 10 percent sugar, corresponding in nutritive value to a soft drink. The other group of rats drank water containing a coal-tar sweetener of the correct composition to match the 10 percent sugar solution in sweetness.

At the end of the test period both groups of rats still weighed the same. Those which drank the sugar ate less dry food because their blood-sugar level was raised and this depressed their appetites—even as you and I. We are in the process of repeating this experiment with obese humans. Here there are two psychological factors which presumably do not operate with rats.

When a person drinks a bottle of No-Cal or puts a saccharin tablet in his coffee, he is reminding himself that he is trying to reduce. This is a psychological prop; it may help a little.

On the other hand, people generally have an exaggerated opinion of the number of calories in a bit of sugar. The correct figure for a level teaspoonful is 18 calories. Persons interviewed recently by Leo Burnett Company in Chicago guessed from 50 to 600, believe it or not.

Many of us have seen examples of the obese dowager who eats two thousand calories at a meal and then puts a saccharin pill in her coffee with an air of "Well, now I've done my reducing for the day!" Or the man who is careful to drink a "dry" beer which is nearly free from dextrose (he calls it "sugar") and forgets that the calories of beer are almost entirely in the alcohol.

It is Dr. Stare's guess that this latter effect will more than balance the psychological-reminder angle of using coal-tar sweeteners and that when the results are in, a year and a half from now, it will probably be found that saccharin and Sucaryl do not help people lose weight. Your Foundation is betting a considerable amount of money that the results will come out this way. Of course, no one can be sure at this stage.

You may wonder, if the coal-tar-sweetener bubble is likely to be punctured this easily, why we are worried about coal-tar sweeteners. Frankly, I am not. The thing which worries me is that sugar is the whipping-boy of the whole food industry. We carbohydrate people have been singularly inarticulate. In consequence, while per capita meat consumption has been gaining, flour and potatoes have been dropping and sugar barely held its own. We Americans now have a strangely distorted diet with only 48.5 percent of the calories derived from carbohydrates, 40 percent from fat and 11.5 percent from protein.

Leading nutritionists are pointing out the chemical connection between this high-fat diet and the formation of cholesterol which partly plugs our arteries and capillaries, restricts the flow of blood, and causes high blood pressure and heart trouble. In 1952 51.6 percent of all deaths in America were attributed to heart disease. In Italy, where the calories in the diet attributed to fat are down to a normal 20 percent (compared to our 40 percent), a man in the 35-year age group has only 21 percent the probability of death from heart trouble as one in the same age group in the United States.

Suppose you take the percentage of the calories in the various national diets due to fat and plot it on a horizontal axis. Then take the probability of a man in the 55-59 age group dying of a heart attack in a given year and plot this along the vertical axis. You have a point for each country for which such statistics are available. The points connect in a smooth curve with the United States at the top with the most fat and most heart disease, Japan at the bottom with the least fat and least heart disease, and all the other countries in order in between.

Of course, this might have been a coincidence so let's try it again with the 45-49 age group. Here the curve is lower; younger men have less heart trouble. But again you get a smooth curve with the United States at the top, Japan at the bottom and the others in order on the curve in between.

This is still inconclusive by itself but the chemical evidence is very convincing. A recent series of between 2,000 and 3,000 autopsies showed that 92 percent of men dying from all causes had in some degree a condition called atherosclerosis. The lining of the coronary artery had become coated with a fatty deposit consisting of 70 percent of cholesterol.

Where does this excess cholesterol come from? Most is synthesized in the liver.

Last November an article by Medes *et al* in the Jour. of Biol. Chem. reported that slices of liver still living and functioning in a nutrient solution generated cholesterol ten times as fast from fatty acid as when they were fed dextrose.

Fatty acid molecules with radioactive $C^{14}$ atoms were fed to men and within hours some of the radioactivity was detected in the blood cholesterol.

Blood cholesterol values, while fluctuating from one individual to another, are higher in countries on high-fat diets. The normal, middle-aged American man is quietly getting ready for the thrombosis which eventually and inevitably will kill him unless something else gets him first. If you put this man on a low-fat diet, it takes just five days for the blood cholesterol to get down to where it should be. The chemistry of this is simple and fascinating; each time through the intestine some of the cholesterol is converted by bacterial action to an insoluble hydrocarbon called squalene, which is eliminated.

If the carbohydrate industries were to recapture this 20 percent of the calories in the U. S. diet (the difference between the 40 percent which fat has and the 20 percent which it ought to have) and if sugar maintained its present share of the carbohydrate market, this change would mean an increase in the per capita consumption of sugar of more than a third with a tremendous improvement in general health.

This will never happen while the present climate of public opinion in regard to sugar remains unchanged. We are in an era—almost unique in world history—when in the United States, and a certain few other favored countries, there is more food available than people can eat. Each food industry has to get up and fight for its place in the limited human stomach.

The ignorance about sugar on the part of even intelligent, well-educated people is astonishing. It often includes a great deal of misinformation. It needs to be removed. It is for these reasons that I am unhappy about advertising which implies that sugar is in some unique sense the cause of obesity. I do not think that coal-tar sweeteners are, in themselves, of surpassingly great importance to the sugar industry. The attitudes toward sugar which No-Cal advertising fosters will, unless vigorously opposed by efforts of the sugar industry, make it impossible for us to grow into the place in the American diet which we should rightfully occupy.

On September 21 the members of Sugar Association voted unanimously to spend $600,000 per year for at least three years to tell the story of sugar in the diet. This decision to stand up and fight was reached after much

debate and prolonged consideration. But there is a point at which any virtue can be carried too far, even that of turning the other cheek. We hope that Leo Burnett can do for sugar what has been done for meat. There will be no bunkum and no ballyhoo, only a process of presenting the facts about sugar in an interesting way.

I hop to see the industry repeat some of this information by printing it on sugar bags. We have missed a wonderful opportunity to tell people the truth about sugar on the billions of sugar bags which customers take home from the grocery.

Last month we selected our liaison man for advertising and public relations. He will work with Leo Burnett Company and Selvage, Lee & Chase, our public relations firm. His name is David Quinlan and he comes to us from the anthracite industry. Like myself, he has much to learn about sugar, but he learns fast.

You have seen our first advertisement. Factual, scientifically correct, simple and easy to comprehend, it is the prototype of many more to follow. At last people who never had a course in biochemistry are going to learn that sugar is what keeps every human being alive and with energy to face our daily problems.

The response from the first advertisement has been most gratifying. Many of us have seen the editorial which FOOD FIELD REPORTER devoted to it. They called our ad a "masterpiece: something which happens once in a copywriter's lifetime." Barricini wants to put one in each box of candy and we are cooperating. Telegrams and letters have poured in both to Sugar Information and, I understand, to member companies. Some are written by crackpots like the one which read "Why don't you use a pistol, it's quicker?" but most, by far, are complimentary and ask for more information. We had an excellent theme lined up for ad number two but under the inspiration of this response Leo Burnett dreamed up another which carries still more punch.

I believe that a powerful reason for this interest is that nutritional quacks have made a dishonest living for many years by extreme and unjustified attacks on sugar in the diet. The fact that the sugar industry never seemed to fight back meant to many people that there was little or nothing which could be said in favor of sugar. It comes as a great surprise that a good case can actually be made for sugar in the diet of even obese people.

Ladies and gentlemen, there is much more which could be told about what your Foundation is doing. Many other projects are showing promise, but we shall have to save them for another day when they are further along. The future for sugar looks very hopeful.

# AGRONOMY

# Effect of Method of Application of Double Superphosphate on the Yield and Phosphorus Uptake by Sugar Beets[1]

W. E. Larson[2]

Optimum phosphate fertilizer placement for sugar beets is probably dependent upon the number of active feeding roots at various soil depths and by the distribution of moisture in the soil during the growing season. Little is known about the quantitative distribution of sugar beet roots at the various stages of growth. However, it seems reasonable that the soil layers containing the largest number of active roots are most desirable for phosphate placement. Results from Colorado (4, 6)[3] have indicated that phosphate must be placed close to the seed for optimum early season uptake. Haddock (2) has shown that later in the season double superphosphate is more available to sugar beets when placed in moist than in drier layers. Since the distribution of roots and moisture in the soil changes during the season, it may be necessary to place phosphate at more than one depth to adequately meet plant needs at all times.

It is the purpose of this paper to report results of two experiments comparing plowing under, broadcasting followed by discing, banding and seed placement of double superphosphate on the yield and phosphorus uptake by sugar beets.

## Plan of Experiments

### 1951 Experiment

Nine treatments including a no phosphate check, broadcasting and plowing under in the fall, broadcasting and discing in the spring, and banding two and five inches deep were used. Each placement treatment was applied at rates of 40 and 80 pounds of $P_2O_5$ per acre as double superphosphate. A complete listing of treatments is included with the yield results.

The nine treatments were arranged in a randomized block design and replicated five times. Each plot was eight rows wide and 50 feet long. Eighty pounds of N per acre were uniformly applied to all plots. The soil type was Manvel silty clay and contained 57 pounds per acre of sodium bicarbonate soluble $P_2O_5$ in the surface soil (5).

The entire plot area near Hardin, Montana, was fall plowed and spring seedbed preparation consisted of heavy discing, floating and construction of single row beds. Sugar beets were planted April 29, 1951.

The sugar beets were thinned carefully June 13. By June 30 a striking growth difference due to phosphate placement was observed and above ground plant samples were harvested for growth comparisons and for phosphorus determinations. Soil moisture was followed throughout the season by the use of gypsum resistance blocks.

---

[1] Joint contribution from the Soil and Water Conservation Branch, ARS, U.S.D.A., and the Montana Agricultural Experiment Station, paper No. 325, Journal Series.

[2] Agent (Soil Scientist), Western Section of Soil and Water Management, and Research Associate in Soils, Montana Agricultural Experiment Station, Bozeman.

[3] Numbers in parentheses refer to literature cited.

Yields were measured October 2 using the two center rows of each plot. Sucrose and tare determinations were made by the Holly Sugar Corporation.

**1952 Experiment**

A similar experiment was conducted in 1952 on a Pryor silty clay soil at the Huntley, Montana, Branch Experiment Station. The surface soil contained 16 pounds per acre of sodium bicarbonate-soluble $P_2O_5$ (5). Treatments were the same as those used in 1951 except that the five-inch depth banding treatment was omitted. In addition each main placement treatment and check was divided and one-half of the plot received 20 pounds of $P_2O_5$ placed in the row with the seed. Rates of phosphate and placement methods were randomized as the main plots and seed placement of phosphate and a check were the split plots. Each subplot was four rows wide and 35 feet long. Main plots were replicated four times. Double superphosphate was used as the source of phosphate. A complete listing of treatments is given with the yield results.

An attempt was made to compare the effectiveness of the main plot placement treatments using radioactive phosphorus. Since $P^{32}$ has a half life of 14.3 days, it was not possible to apply tagged phosphate in the fall and measure it quantitatively the following summer. Thus, all treatments were applied as scheduled using non-active phosphate. Then, at planting time, 40 pounds of radioactive double superphosphate per acre were banded three inches deep and three inches to the side of one row of each main plot not receiving phosphate with the seed. It was assumed that the greater the availability of the non-active treatments the less the plant would draw on the active phosphate. Thus, there would be an inverse relation between the activity of the plant material and the availability of the placement method. Fried and Dean (1) have discussed this general relation. Combined leaf and petiole samples were removed from the plants at three dates choosing the latest mature leaves as described by Ulrich (7). Yields were measured by harvesting the two center rows of each subplot. The radioactive row was not used for yield determinations. The sugar beets were washed, tared, weighed and sugar determined by the Great Western Sugar Company.

Total phosphorus and $P^{32}$ were measured on the combined leaf and petiole samples[4]. Total phosphorus was determined using the method of Koenig and Johnson (3) following ashing in an electric furnace with magnesium nitrate.

## Results

**1951 Experiment**

The effect of rates and methods of application of phosphate on the yield, relative early growth, percent phosphorus in the foliage and the percent sucrose in the roots is given in Table 1.

The mean yield increases for 40 and 80 pounds of $P_2O_5$ per acre over the no phosphate check were 2.1 and 2.7 tons per acre, respectively. Increasing rates of phosphate also increased early growth and percent phosphorus in the foliage.

[4] $P^{32}$ determinations were made by Frank S. Watanabe at Fort Collins, Colorado.

**Table 1.—The Effect of Method and Rate of Application of Double Superphosphate on the Yield, Early Growth and Phosphorus Content of Sugar Beets.**

| Treatment No. | Treatment | Yield Tons/Acre | Relative Growth on June 30 | Percent P in Foliage June 30 | Sucrose (roots) % |
|---|---|---|---|---|---|
| 1 | Check—no phosphate | 12.6 | 100 | .396 | 17.8 |
| 2 | 40 lb. $P_2O_5$/A. broadcast and plowed under, fall | 15.3 | 145 | .459 | 17.4 |
| 3 | 80 lb. $P_2O_5$/A. broadcast and plowed under, fall | 15.8 | 185 | .475 | 17.7 |
| 4 | 40 lb. $P_2O_5$/A. broadcast and disced in the spring on fall plowed land | 15.8 | 196 | .443 | 17.4 |
| 5 | 80 lb. $P_2O_5$/A. broadcast and disced in the spring on fall plowed land | 15.6 | 226 | .461 | 17.6 |
| 6 | 40 lb. $P_2O_5$/A. banded 2" deep and 2" to the side of the seed at planting time | 14.2 | 134 | .386 | 17.7 |
| 7 | 80 lb. $P_2O_5$/A. banded 2" deep and 2" to the side of the seed at planting time | 14.9 | 151 | .418 | 17.9 |
| 8 | 40 lb. $P_2O_5$/A. banded 5" deep and 2" to the side of the seed at planting time | 13.6 | 158 | .411 | 17.8 |
| 9 | 80 lb. $P_2O_5$/A. banded 5" deep and 2" to the side of the seed at planting time | 15.0 | 160 | .454 | 17.4 |

Rates of phosphate were significantly different at the 1 percent level for yields, relative growth and percent phosphorus in the foliage.
Methods of phosphate were significantly different at the 1 percent level for yields, relative growth and percent phosphorus in the foliage.
No treatment significantly affected the percent sucrose in the roots.

Plowed under and disced in phosphate produced significantly higher yields than did banding at two- or five-inch depths. For example, yields for plowed under phosphate were 1.1. tons per acre greater than the mean of the two banding treatments. There was no difference in yield between plowed under or disced in phosphate, however. Plowed under and disced in phosphate also produced greater early growth and percent phosphorus in the foliage than did the banding treatments. There was no interaction between rates and methods of application.

The percent sucrose in the roots was not affected by any treatment.

**1952 Experiment**

The relative growth at thinning time, stand, yield and sucrose content of sugar beets as influenced by rate and method of application are presented in Table 2.

The mean sugar beet yield increase from plowed under phosphate over banded or disced in phosphate was 2.6 and 2.2 tons per acre, respectively. Phosphate placed with the seed in addition to the regular rate and placement treatments produced a marked response in sugar beet growth at thinning time but had no effect on final yields.

Forty and 80 pounds of $P_2O_5$ per acre produced a 7.4 and 9.0 tons per acre increase in yields over the no phosphate check. A 20-pound per acre

**Table 2.—Effect of Method and Rate of Application of Double Superphosphate on the Early Growth, Stand, Yield and Sucrose Content of Sugar Beets.**

| Treatment No. | Pounds $P_2O_5$ Per Acre | Method of Application | Yield Tons Per Acre | Relative Growth at Thinning Time (5/27) | Stand % | Sucrose (roots) % |
|---|---|---|---|---|---|---|
| 1a | 0 | Check | 11.3 | 100 | 73 | 17.4 |
| 1b | 20 | Applied with the seed[1] | 15.3 | 220 | 86 | 17.6 |
| 2a | 40 | Applied broadcast and plowed under in fall | 20.0 | 138 | 89 | 17.4 |
| 2b | 60 | Same as 2a plus with the seed | 20.2 | 260 | 90 | 17.3 |
| 3a | 80 | Same as 2a | 22.4 | 188 | 89 | 17.4 |
| 3b | 100 | Same as 2a plus with the seed | 21.9 | 327 | 95 | 17.4 |
| 4a | 40 | Applied broadcast in spring, disced on fall plowed land | 18.8 | 198 | 91 | 17.3 |
| 4b | 60 | Same as 4a plus with the seed | 19.3 | 214 | 95 | 17.0 |
| 5a | 80 | Same as 4a | 19.0 | 178 | 92 | 17.4 |
| 5b | 100 | Same as 4a plus with the seed | 18.5 | 199 | 86 | 16.9 |
| 6a | 40 | Banded 3" deep and 2" to the side of seed at planting time | 17.3 | 118 | 81 | 17.6 |
| 6b | 60 | Same as 6a plus with the seed | 18.4 | 288 | 87 | 17.4 |
| 7a | 80 | Same as 6a | 19.5 | 153 | 81 | 17.6 |
| 7b | 100 | Same as 6a plus with the seed | 19.1 | 256 | 86 | 17.4 |

[1] Phosphate applied with the seed at the rate of 20 pounds of $P_2O_5$ per acre.

Rates of phosphate were significantly different at the 1 percent level for relative growth and yield.

Methods of phosphate application were significantly different at the 1 percent level for relative growth and yield and at the 5 percent level for stand.

Phosphate applied with the seed produced significant increases at the 1 percent level for relative growth, and increased stand and yield at the 1percent level only when applied with no other phosphate.

No treatment significantly affected the percent sucrose in the roots.

application of $P_2O_5$ with the seed produced a 4.0 ton per acre increase over the check. Increasing rates of phosphate increased the early growth. There was no rate times method interaction.

Stand of sugar beets at harvest time was increased by all phophate applications. The banding treatment had fewer sugar beet plants than did either of the other two application methods. This was not due to disturbance by the banding equipment since all plots were treated the same except for the rate of application. Presumably the lowered stand was due to loss from disease after thinning since a heavy stand of beets was present just prior to thinning.

No rate or method of application had any effect on the percent sucrose in the root at harvest time.

The percent of the total phosphorus in the foliage and the percent of the total phosphorus in the foliage derived from the radioactive fertilizer at three sampling dates as influenced by rate and method of application are given in Table 3. Sugar beets grown on plowed under phosphate contained much greater quantities of phosphorus at all sampling dates than did those grown on other treatments. Eighty pounds of $P_2O_5$ produced consistently higher amounts of phosphorus in the foliage when plowed under than did 40 pounds, but this amount was not consistently better on spring disced or banded phosphate.

**Table 3.—The Effect of Method and Rate of Application of Double Superphosphate on the Percent of Total Phosphorus and the Percent of the Total Phosphorus Derived from Radioactive Fertilizer in Sugar Beet Foliage.**

| Treatment No.[1] | Percent Total Phosphorus in Foliage | | | Percent of Total Phosphorus in Foliage Derived from Radioactive Fertilizer | | |
|---|---|---|---|---|---|---|
| | June 26 | Aug. 1 | Aug. 28 | June 26 | Aug. 1 | Aug. 28 |
| 1a | 0.251 | 0.164 | 0.138 | 87.1 | 45.5 | 38.7 |
| 2a | 0.334 | 0.181 | 0.173 | 11.5 | 21.4 | 20.0 |
| 3a | 0.378 | 0.231 | 0.209 | 5.3 | 9.6 | 11.2 |
| 4a | 0.213 | 0.188 | 0.170 | 23.4 | 32.2 | 27.6 |
| 5a | 0.237 | 0.192 | 0.164 | 26.0 | 27.2 | 20.2 |
| 6a | 0.245 | 0.196 | 0.169 | 25.6 | 24.5 | 22.2 |
| 7a | 0.238 | 0.210 | 0.196 | 22.6 | 20.8 | 16.0 |
| L.S.D. (.05) | 0.032 | 0.030 | 0.025 | 9.4 | 5.1 | 5.4 |
| L.S.D. (.01) | 0.043 | 0.041 | 0.034 | 12.8 | 6.8 | 7.2 |

[1] Treatment numbers refer to treatments listed in Table 2.

Because the radioactive phosphorus was applied in addition to the regular treatments, the amounts found in the plant would be expected to be inversely related to the availability of the original treatment. Thus, plants from the higher yielding plowed under phosphate contained much smaller quantities of phosphorus from the radioactive fertilizer than did the other treatments. The increase during the season in the quantities of phosphorus in the plant from the radioactive fertilizer on the plowed under treatments indicates a relative decrease in availability as the season progressed. Banded phosphate appeared to become more available as the season progressed whereas the disced phosphate was not much affected.

## Discussion

The data available indicate that an ideal method of application may be a shallow placement close to the seed for early stimulation together with a deep placement where moisture conditions are more favorable later in the season. Plowing under phosphate appears to be an easy, practical way to effect such a placement. The stimulation due to phosphate placed with the seed indicates that it must be in close proximity to the seed for seedling vigor. This indication is in agreement with other work (4, 6). On the other hand, Haddock's data (2) show that deep banded phosphate is desirable late in the season and particularly under dry conditions.

The placement effected by broadcasting fertilizer, plowing and lightly discing the soil was determined. To establish this, ammonium nitrate of a particle size similar to commercial double superphosphate was broadcast and the soil plowed and lightly disced. The soil was sampled immediately, dried and analyzed for nitrate. The experiment was conducted adjacent to the 1952 experiment and plowing conditions were similar. Fourteen, 47 and 39 percent of the fertilizer was found in the 0-2, 2-5 and 5-7 inch layers, respectively. In addition, a banding effect was present between the plow slices. It is realized that many factors such as soil, moisture and type of plowing could affect fertilizer placement. However, this experiment probably represents good plowing conditions on a fine textured soil.

In the experiments reported herein yields and phosphorus uptake demonstrated the superiority of fall broadcasting and plowing under phosphate over the banding treatments. It is believed that the favorable comparison between disced in and plowed under phosphate in 1951 resulted from a deep incorporation caused by heavy discing and followed by ridging each row prior to planting. In contrast, the inferiority of disced in phosphate in 1952 was due to shallow incorporation by light discing and without construction of beds or ridges. Banded phosphate may have been too far distant from the seedling roots to compare favorably with plowed under phosphate.

Soil moisture records from the two experiments as indicated by gypsum resistance blocks are not reported herein. However, they do show that the experiments were irrigated as often as has been found necessary for maximum yields at this location.

On some soils plowed under phosphate may be subject to large amounts of fixation because most of it is in intimate contact with soil. However, fixation was not serious on the two soils studied since considerably more time elapsed between application and planting on the higher yielding fall plowed under phosphate than for other treatments. Spring plowed under phosphate would be expected to be as good or better than fall plowed phosphate.

## Summary

Two experiments compared the effect of plowing under, broadcasting, banding and seed placement of double superphosphate at various rates of application on the yield, phosphorus uptake, stand, early growth and percent sucrose of sugar beets.

In a 1951 experiment fall plowed under phosphate and spring disced phosphate produced higher yields, better early growth and greater phosphorus concentrations in the foliage than did banding at either 2- or 5-inch depths. The mean yield increase for 40 and 80 pounds of $P_2O_5$ per acre strategically placed was 3.0 and 3.1 tons per acre, respectively.

In 1952, 40 and 80 pounds of $P_2O_5$ per acre increased yields by 8.7 and 11.1 tons per acre respectively, when fall plowed under. Mean yields for plowed under phosphate were greater than disced or banded phosphate by 2.2 and 2.3 tons per acre respectively. The superiority of plowed under phosphate was also demonstrated by better early growth and greater phosphorus concentrations. An indirect method of determining the relative effectiveness of phosphate placements and using radioactive phosphorus also demonstrated the superiority of a plowed under treatment. Phosphate applied with the seed produced early growth stimulation but had no effect on yield when applied in combination with other phosphate treatments.

An experiment to determine the placement effected by broadcasting and plowing under fertilizer on a fine textured soil showed that 14, 49 and 37 percent was placed at 0-2, 2-5 and 5-7 inch depths respectively. In addition, a banding effect was apparent between the plow slices.

It is believed that, in the two experiments reported, the superiority of plowing under phosphate was due to a small amount being near the surface and thus accessible to the young seedling and at the same time a large amount was placed deep where moisture is more favorable later in the season.

ACKNOWLEDGMENT

Appreciation is expressed to the Holly Sugar Corporation and the Great Western Sugar Company for financial support and for sugar and tare determinations.

## Literature Cited

(1) FRIED, M. and DEAN, L. A.
1952. A concept concerning the measurement of available soil nutrients. Soil Science 73:263-271.

(2) HADDOCK, J. L.
1952. The influence of soil moisture condition on the uptake of phosphorus from calcareous soils by sugar beets. Soil Sci. Soc. Amer. Proc. 16:235-238.

(3) KOENIG, R. A. and JOHNSON, C. R.
1942. Colorimetric determination of phosphorus in biological materials. Ind. Eng. Chem. ,Anal. Ed. 14:155-156.

(4) OLSEN, S. R. et al
1950. Utilization of phosphorus by various crops as affected by source of material and placement. Colo. Agr. Expt. Sta. Tech. Bul. 42.

(5) OLSEN, S. R. et al
1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U. S. Dept. of Agr. Cir. (In Press).

(6) SCHMEHL, W. R., et al
1952. Effect of type of phosphate material and method of application on phosphate uptake and yield of sugar beets. Proc. Am. Soc. Sug. Beet Tech. 1952:153-158.

(7) ULRICH, ALBERT
1948. Diagnostic techniques for soils and crops. H. B. Kitchen, Ed. The American Potash Institute. Washington, D. C. pp. 157-198.

# A Study of the Effect of Magnesium Sulfate on Yield and Sucrose Content of Sugar Beets

E. M. Holst and C. E. Cormany[1]

## I. Introduction

Apart from the role of being an integral part of the chlorophyll molecule, magnesium has a definite effect on rate of photosynthesis (3)[2]. In borderline cases of low magnesium in the substrate on which a plant is depending for nutrition, chlorophyll may be present in sufficient amounts so that no chlorosis is produced, yet photosynthesis proceeds at a slow rate. An increase of available magnesium in the substrate at this critical level increases photosynthesis with no marked further increase in chlorophyll (3).

Magnesium is believed by some workers to be intimately associated with movement of phosphates within the plant (4). Since many calcareous soils are notably deficient in phosphorus, it may be that an abundance of magnesium would increase the efficiency of phosphorus utilization within the plant.

There is some evidence that addition of magnesium sulfate to soils increases the availability of reverted phosphates and increases the uptake of phosphorus by plants (2).

It has been reported that magnesium sprayed on sugar beets in the Arkansas Valley of Colorado increased percent sucrose to a significant degree (1).

In view of these findings of other workers, it was believed that the subject of magnesium fertilization of sugar beets deserved some further study.

The objectives of the experiment were: 1—to determine whether magnesium sulfate at several rates of application would affect sugar percentage, and 2—to discover whether soil addition would have the same effects as foliage sprays.

## II. Procedure

The experiment was carried out in the Arkansas Valley of Colorado, near Swink, on Rocky Ford clay loam. Ten treatments were designed as follows:

1. Check. Sidedresser used empty on these plots to get the effect of soil loosening which would occur on plots receiving magnesium sulfate.
2. 10 lbs./A magnesium sulfate sidedressed July 1, 1952, in water furrows, about six inches deep.
3. 20 lbs./A magnesium sulfate sidedressed as in 2.
4. 30 lbs./A magnesium sulfate sidedressed as in 2.
5. 40 lbs./A magnesium sulfate sidedressed as in 2.
6. Check. These plots sprayed with tap water.

---

[1] Associate Agronomist, Holly Sugar Corporation, Swink, Colorado, and Chief Agronomist, Holly Sugar Corporation, Sheridan, Wyoming, respectively.

[2] Numbers in parentheses refer to literature cited.

7. 10 lbs./A magnesium sulfate sprayed on foliage in four applications beginning July 1 at 14-day intervals.
8. 20 lbs./A magnesium sulfate sprayed as in 7.
9. 30 lbs./A magnesium sulfate sprayed as in 7.
10. 40 lbs./A magnesium sulfate sprayed as in 7.

The experimental design chosen was the split plot variation of randomized blocks, method of application (spraying vs. sidedressing) being the main plots, subdivided by rates of application to give the subplots.

Subplot size was four rows (22 inches) by 29 feet long.

Five replications were used.

Sugar beets of variety MW 111 were planted.

For magnesium sulfate source, commercial grade Epsom salt was used.

All plots received a uniform application of 20 lbs./A nitrogen as ammonium nitrate and 50 lbs./A phosphorus penta-oxide as concentrated superphosphate, sidedressed after thinning.

The inside two rows of each four row subplot were harvested for yield, percent sugar and root count data.

## III. Results

Yield as tons of roots per acre and gross sugar per acre are reported in Table 1. Percent sucrose (based on two 15-beet samples from each plot) and number of beets per 100 feet of row also appear in Table 1. Some pertinent data on the analysis of variance appear in Table 2.

No differences in growth of tops, color and other visual characters were noted during the growing season.

**Table 1.—Treatment and Acre Yield of Beets—Magnesium Sulfate Applied at Various Rates.**

| Treatment | Acre Yield | | Percent Sucrose | Number of Beets per 100' of Row |
|---|---|---|---|---|
| | Lbs. of Gross Sugar | Tons of Roots | | |
| 1. Zero $MgSO_4$ Sidedressed | 4,270 | 12.07 | 17.6 | 94.4 |
| 2. 10 lbs./A $MgSO_4$ Sidedressed[1] | 4,516 | 12.69 | 17.8 | 104.4 |
| 3. 20 lbs./A $MgSO_4$ Sidedressed | 4,204 | 12.10 | 17.3 | 97.2 |
| 4. 30 lbs./A $MgSO_4$ Sidedressed | 4,416 | 12.41 | 17.8 | 96.4 |
| 5. 40 lbs./A $MgSO_4$ Sidedressed | 4,256 | 12.28 | 17.4 | 98.0 |
| 6. Zero $MgSO_4$ Sprayed[2] | 4,532 | 12.91 | 17.5 | 110.4 |
| 7. 10 lbs./A $MgSO_4$ Sprayed | 4,224 | 12.15 | 17.4 | 104.0 |
| 8. 20 lbs./A $MgSO_4$ Sprayed | 4,500 | 12.68 | 17.7 | 105.2 |
| 9. 30 lbs./A $MgSO_4$ Sprayed | 4,292 | 12.24 | 17.5 | 98.8 |
| 10. 40 lbs./A $MgSO_4$ Sprayed | 4,876 | 13.42 | 18.2 | 110.8 |
| General Mean | 4,408.6 | 12.50 | 17.6 | 101.96 |
| Sig. Diff. (5%) | NS[3] | NS | NS | NS |

[1] Sidedressed in water furrows, 6 inches deep, on 7-1-52; sidedresser was used empty on check plot.
[2] Sprayed on foliage in four applications beginning 7-1-52 and repeated at 14-day intervals. Tap water alone used on check plot.
[3] No significant difference at the 5 percent level.

Table 2.—Variance Table for Data in Table 1.

| Source of Variation | Degrees of Freedom | Mean Squares | | | |
|---|---|---|---|---|---|
| | | Gross Sugar | Root Yield | Percent Sucrose | Beets per 100' of Row |
| Blocks | 4 | 2853258.00 | 23.356 | 0.107 | 134.680 |
| Method | 1 | 290322.00 | 1.719 | 0.039 | 752.720 |
| Error (a) | 4 | 1625982.00 | 11.940 | 0.205 | 508.920 |
| Total (a) | (9) | | | | |
| Rate | 4 | 81268.00 | 0.424 | 0.108 | 76.880 |
| Rate x Method | 4 | 328232.00 | 1.248 | 0.644 | 117.92 |
| Error (b) | 32 | 405010.00 | 3.372 | 0.256 | 83.05 |
| Total | 49 | | | | |
| Calculated "F" (Method) | | (5.600)NS[1] | (6.946)NS | (5.256)NS | 1.479 NS |
| Calculated "F" (Rate) | | (4.984)NS | (7.952)NS | (2.370)NS | (1.080)NS |
| Calculated "F" (Rate x Method) | | (1.234)NS | (2.702)NS | 2.516 NS | 1.419 NS |

Note: "F" Values in parentheses indicate error mean square greater than the other mean square used to compute the ratio.

[1] Not significant.

## IV. Discussion

Treatment 10 (40 lbs./A magnesium sulfate sprayed on the foliage) gave the largest increase in root yield, and the highest percent sucrose. Although these differences are not statistically significant, the problem of application of magnesium sulfate to beets is believed to deserve further study for two reasons:

1—The interaction variance for percent sucrose when compared with the error variance in the "F" test closely approached significance. It is possible that, with a few more replications, this interaction would have been significant. 2—The data presented here are not in agreement with the data presented in (1). Alexander and Cormany reported an increase in percent sucrose when magnesium sulfate in aqueous solution at 20 lbs./A was sprayed on the foliage. The work presented in this paper should be repeated with increased replication, to determine whether the results reported in (1) can be confirmed.

Three reasons which could help account for the disagreement on results between this paper and (1) are the use of a different variety of beets, differences in growing season between the two years, and differences in soil fertility and irrigation practices between the two experimental plots.

## V. Summary

1. An experiment is outlined and data presented regarding the use of magnesium sulfate applied to sugar beets.

2. All data collected point to negative results with this chemical on sugar beets of variety MW 111 in the locale of Swink, Colorado, on Rocky Ford clay loam, for a growing season similar to 1952.

## Literature Cited

(1) ALEXANDER, J. T. and CORMANY, C. E.
1950. Effects of growth-promoting substances on sugar beets. Am. Soc. Sugar Beet Tech., Proc. pp. 390-392.

(2) BARTHOLOMEW, R. P.
1933. The availability of phosphatic fertilizers. Ark. Agr. Expt. Sta. Bul. 289.

(3) CURTIS, D. F., and CLARK, D. G.
1950. An introduction to plant physiology. McGraw-Hill, New York, N. Y.

(4) MEYER, B. S. and ANDERSON, D. B.
1939. Plant Physiology. D. Van Nostrand. New York, N. Y.

# Response of Sugar Beets to Nitrogen Fertilizer in the Imperial Valley, California[1]

B. A. Krantz and A. J. MacKenzie[2]

To obtain information as to the optimum fertility practices for the growing of sugar beets in the Imperial Valley area of California three experiments were conducted during the 1951 season. Two of the experiments were designed to determine the nitrogen, phosphorus and potash rquirements of sugar beets, to determine the effect of manure and to compare single vs. split application of nitrogen. The third experiment was designed to compare the nitrogen requirement of U. S. 35/2, a high sugar strain, with that of the standard U. S. 22/3. The three experiments were conducted with farmer cooperators at three locations.

There were marked responses to nitrogen application, but no significant response to phosphorus, potash or manure application. The discussion in this paper will be limited to the effects of nitrogen application upon nitrate level in the plant and the yield and quality of the sugar beets.

## Methods and Materials

The nitrogen fertility experiments were conducted on a Meloland fine sand at the Simons ranch near Brawley, and on a Holtville silty clay loam at the Glud ranch near Calexico. At the Simons ranch seven to nine inches of top soil had been removed from the experimental area by leveling during the previous season. This site was purposely chosen as it was assumed that the phosphorus and nitrogen level of the soil would be relatively low. At the Glud location the experimental area had been in beets in 1951 and had been in alfalfa for the previous three years.

Both experiments were laid out in a four x four balanced lattice design with five replications. The plots were four rows, 10 feet by 60 feet. Original plans were to conduct identical experiments at the two locations. However, it became apparent early in the season that the highest rate of nitrogen at the Simons location would not be sufficient to carry the plants through until the end of the season. Nitrogen rates were, therefore, increased for this location up to a maximum treatment of 400 lbs./A. The step-ups were made on the 160-pound rates which still had adequate nitrogen as indicated by plant growth and petiole composition (5,000 p.p.m. $NO_3$-N).

The treatments involving rates and time of application of nitrogen for the two locations are given in Tables 1 and 2. All preplanting fertilizer was applied in a band 3 inches to one side and 3 inches below the seed. Phosphorus was applied preplant in all nitrogen comparisons at the rate of 200 lbs. $P_2O_5$/A. Ammonium nitrate was used for all nitrogen sidedressing applications. U. S. 56 seed was planted in dry single row sloping beds 30 inches apart and irrigated in every other furrow. The Glud experiment was planted October 20 and the Simons experiment November 3. After emergence the plants were thinned to 6 to 7 inches apart.

---

[1] Contribution of the Western Section of Soil and Water Management, Soil and Water Conservation Research Branch A.R.S., U.S.D.A.

[2] Senior Soil Scientist and Soil Chemist, respectively, U.S.D.A.

The nitrogen variety experiment was conducted on a Holtville loam soil at the D'Arrigo ranch near Brawley. The field had been in lettuce during 1950 and in alfalfa previously. A split plot design was used with six replications. The variety whole plots were split into three rates of nitrogen. The whole plot size was 270 feet x 14 feet (8 rows) and the split plot size was 90 feet x 14 feet. The sugar beets were planted in double rows 12 inches apart on 42 inch beds January 26, 1951. The variety and nitrogen treatments are shown in Table 3.

### Plant Sampling and Chemical Analysis Procedures

At each sampling date twenty sugar beet petioles of recently matured leaves were selected at random from each plot. The petioles were cut up into sections one inch in length and dried in a convection oven at 75° C. The sample was ground in a Wiley mill to pass a 40-mesh screen, bottled and stored for chemical analysis.

The method of Johnson and Ulrich (2)[3] for the extraction and determination of nitrates in dried plant material was followed for the analysis of the petiole samples. Ulrich (3, 4) has found the nitrate content of the petiole to be closely related to nitrogen applications, sugar percentages and beet yields. Haddock (1) has recently shown that the soluble organic nitrogen fraction in sugar beet petioles is more closely related to the factors of quality of sugar beet roots than is nitrate-nitrogen. It was also shown, however, that the nitrate-nitrogen content of sugar beet petioles is highly correlated with sucrose and purity of beet roots. Because of the simplicity and rapidity of the nitrate-nitrogen determination and its adaptability for practical purposes it was considered as a satisfactory index of nitrogen nutrition.

### Results and Discussion

Widely different responses to nitrogen were obtained in the two fertility experiments. Data for the yield and quality of sugar beets are shown in Tables 1 and 2.

At the Simons ranch the acre yield of sugar beets was increased by more than 14 tons. However, as pointed out above the nitrogen level on this field was lower than normal because top soil had been removed by leveling. The nitrogen level of the soil was so low that only 9 tons of beets were produced where no nitrogen was added. There was a significant increase in beet and sugar tonnage up through 160 pound per acre rate of nitrogen application. The upward trend in yield above the 160-pound level was not significant. A gradual decrease in sugar percentage with nitrogen application was obtained but the magnitude of the reduction was the greatest at the higher rates of application. Since the high rates of application were made late in the season the depressing effect may have been greater than if they had been applied at normal sidedressing time.

---

[3] Numbers in parentheses refer to literature cited.

**Table 1.—Yield and Quality of Sugar Beets and Seasonal Petiole Composition as Influenced by Nitrogen Fertilizer. James Simons Ranch, Brawley, 1951 Season.**

| Nitrogen Applied Lbs./A. | Yield Beets T/A. | Sucrose % | Purity % | Gross Sugar T/A. | Nitrate-Nitrogen in Beet Petioles 3/16 ppm | 4/18 ppm | 5/7 ppm | 5/31 ppm | 6/21 ppm |
|---|---|---|---|---|---|---|---|---|---|
| 1. 0 | 9.01 | 19.1 | 86.9 | 1.72 | 118 | 70 | | | |
| 2. 0 + 40 sidedressed[1] | 14.50 | 18.8 | 86.7 | 2.74 | 312 | 95 | 75 | | |
| 3. 0 + 80 sidedressed[1] | 15.83 | 18.2 | 85.8 | 2.87 | 629 | 127 | 103 | 52 | |
| 4. 0 + 160 sidedressed[1] | 18.72 | 18.3 | 85.6 | 3.43 | 5,631 | 606 | 75 | 46 | |
| 5. 40 | 13.84 | 18.4 | 86.1 | 2.56 | 282 | 98 | 61 | | |
| 6. 40 + 40 sidedressed[1] | 14.40 | 18.6 | 85.4 | 2.68 | 399 | 72 | | | |
| 7. 40 + 120 sidedressed[2] | 20.03 | 17.9 | 87.1 | 3.59 | 5,423 | 865 | 100 | 42 | |
| 8. 40 + 200 sidedressed[3] | 21.60 | 17.1 | 85.0 | 3.71 | 4,178 | 2,757 | 196 | 69 | |
| 9. 40 + 280 sidedressed[4] | 21.22 | 16.9 | 85.1 | 3.58 | 4,028 | 2,635 | 2,158 | 381 | 70 |
| 10. 40 + 360 sidedressed[5] | 23.15 | 16.2 | 82.5 | 3.73 | 4,042 | 4,645 | 2,456 | 358 | 105 |
| L.S.D. (05) | 3.74 | 1.0 | N.S. | 0.22 | | | | | |
| (01) | 4.98 | 1.4 | | 0.29 | | | | | |
| C.V. % | 16.2 | 4.5 | 2.5 | 5.4 | | | | | |

[1] Sidedressing at thinning, January 17.
[2] Split sidedressing, 80 lbs./A. at thinning and 40 lbs./A. on March 5.
[3] Split sidedressing, 120 lbs./A. at thinning and 80 lbs./A. on March 19.
[4] Split sidedressing, 120 lbs./A. at thinning, 80 lbs./A. on March 19 and 80 lbs./A. on April 23.
[5] Split sidedressing, 120 lbs./A. at thinning, 160 lbs./A. on March 19 and 80 lbs./A. on April 23.

Analysis of the petioles (Table 1) shows that the nitrate content of the petioles in the 40- and 80-pound treatments had dropped below the "critical level"[4] by March 16 (17 weeks before harvest). The nitrate level in the 160-pound treatments was still high but dropped rapidly and was below the 1,000 p.p.m. value by April 18 (12 weeks before harvest). At this date the nitrate level of the 240-pound plots was still high but had dropped sharply by May 7 (9 weeks before harvest). These results indicate that optimum sugar yields are obtained when the nitrates in the petiole are maintained above the critical level until about mid-April. In treatments 9 and 10 where the nitrate remained high in May, the sugar percentage was reduced so much as to overshadow any increase in beet yield.

Since the weather is hot prior to harvest, it is possible that growth had slowed up or stopped a considerable time before harvest. Thus the period between the depletion of the nitrates in the petiole and the end of growing season is not as long as indicated. Work is being continued along this line with earlier harvest dates included to establish optimum time for plant nitrate depletion in relation to harvest time.

In the Glud experiment (Table 2) there was no yield response to nitrogen. The fertility level in the soil was high enough that 22.4 tons of beets were produced in the no-nitrogen treatments. Even though the nitrogen level in the soil was high enough that there was no response to nitrogen application, the added nitrogen did not significantly depress the sugar per-

[4] Ulrich defines the critical level of a given nutrient as that concentration at which "growth is first retarded in comparison to plants with a higher concentration of the same nutrient" (5). Through experience he has found the critical level for nitrate nitrogen in the petioles to be about 1,000 p.p.m. on a dry weight basis.

**Table 2.—Yield and Quality of Sugar Beets and Seasonal Petiole Composition as Influenced by Nitrogen Fertilizer. Paul Glud Ranch, Calexico, 1951 Season.**

| Nitrogen Applied Lbs./A. | Yield Beets T/A. | Sucrose % | Purity % | Gross Sugar T/A. | Nitrate-Nitrogen in Beet Petioles 3/12 ppm | 4/9 ppm | 5/4 ppm | 5/28 ppm |
|---|---|---|---|---|---|---|---|---|
| 1. 0 | 22.4 | 19.1 | 89.0 | 4.28 | 2,523 | 535 | 195 | 215 |
| 2. 0 + 40 sidedressed[1] | 20.4 | 19.4 | 88.8 | 3.96 | 1,993 | 604 | 309 | 273 |
| 3. 0 + 80 sidedressed[1] | 22.0 | 19.0 | 88.0 | 4.18 | 2,004 | 807 | 245 | 504 |
| 4. 0 + 160 sidedressed[1] | 23.9 | 18.2 | 84.8 | 4.35 | 2,328 | 1,021 | 404 | 571 |
| 5. 40 | 23.4 | 18.8 | 87.3 | 4.26 | | | | |
| 6. 40 + 40 sidedressed[1] | 21.8 | 19.2 | 87.2 | 4.19 | | | | |
| 7. 40 + 120 sidedressed[1] | 21.9 | 19.4 | 86.1 | 4.25 | | | | |
| 8. 40 + 120 sidedressed[2] | 22.5 | 18.7 | 86.6 | 4.21 | 2,030 | 1,855 | ..... | ..... |

[1] Sidedressing at thinning, December 11.
[2] Split sidedressing, 80 lbs./A. at thinning and 40 lbs./A. on March 12.

centage. Purity was slightly depressed by nitrogen application. However, the amount of depression was small and the purity was relatively high throughout the experiment. There were no significant differences in yield of sugar—the zero nitrogen treatment yielding 4.28 tons/A.

March 12 the nitrate-nitrogen content of petioles was still high in all treatments, including the zero nitrogen plots. Likewise, there was no appreciable growth response to nitrogen application up through this date. By April 9 (11 weeks before harvest) all but the 160-pound plots had dropped below the critical value. However, this late difference did not appear to influence yield.

In the Variety x Nitrogen experiment the response due to nitrogen was far greater than that due to varieties (Table 3).

**Table 3.—Effect of Nitrogen Fertilizer Upon the Yield, Quality, and Seasonal Petiole Composition of Two Related Varieties of Sugar Beets. D'Arrigo Bros., Brawley, 1951 Season.**

| Variety | Nitrogen Applied Lbs./A. | Yield Beets T/A. | Sucrose % | Purity % | Gross Sugar T/A. | Nitrate-Nitrogen in Beet Petioles 4/18 ppm | 5/9 ppm | 6/1 ppm | 6/22 ppm |
|---|---|---|---|---|---|---|---|---|---|
| U. S. 22/3 | 40[1] | 13.6 | 18.0 | 86.9 | 2.44 | 124 | 192 | 55 | .... |
| | 160[2] | 17.2 | 16.3 | 83.0 | 2.79 | 527 | 4,241 | 496 | .... |
| | 320[3] | 18.2 | 14.0 | 79.3 | 2.55 | 3,204 | 12,732 | 4,280 | 1,648 |
| U. S. 35/2 | 40[1] | 12.2 | 19.0 | 87.9 | 2.31 | 97 | 108 | 70 | .... |
| | 160[2] | 15.6 | 18.0 | 86.4 | 2.81 | 223 | 3,173 | 172 | .... |
| | 320[3] | 17.8 | 15.9 | 82.6 | 2.83 | 1,811 | 11,463 | 2,510 | 970 |
| Both Varieties | 40 | 12.9 | 18.4 | 87.4 | 2.38 | | | | |
| | 160 | 16.4 | 17.2 | 84.7 | 2.80 | | | | |
| | 320 | 18.0 | 15.0 | 81.0 | 2.69 | | | | |
| L.S.D. (05) (Nitrogen Means) | | 1.5 | 0.5 | | 0.24 | | | | |
| L.S.D. (01) (Nitrogen Means) | | 2.0 | 0.7 | | 0.33 | | | | |

[1] 40 lbs./A. sidedressed on March 6.
[2] 80 lbs./A. sidedressed on March 6 and 80 lbs./A. sidedressed on April 20.
[3] 160 lbs./A. sidedressed on March 6 and 160 lbs./A. sidedressed on April 20.

Nitrogen application increased the average yield of both varieties from 12.9 to 18.0 tons per acre. There was a slight, though significant, increase of the 320-pound nitrogen treatment over that of the 160-pound plots. However, this yield increase due to the last increment of nitrogen was overshadowed by the marked decrease in sugar percentage so that the sugar tonnage was slightly decreased. The sugar percentage in U. S. 35/2 was somewhat higher than that of U. S. 22/3 but there was no appreciable difference between varieties in beet or sugar yield.

Since a wide range in the nitrogen level was necessary to attain the objectives of this experiment, a second sidedressing was made on the medium and high treatments April 20.

These applications were reflected in the petiole nitrate content of the May 9 sampling (Table 3). The nitrates in the 320-pound treatment were the highest observed in any experiment and were still high on June 1 and June 22. The sugar percentage was reduced 2.2 percent by the last increment of nitrogen.

The nitrate content of U. S. 35/2 was consistently lower that that of U. S. 22/3. This was especially true in the highest nitrogen treatment late in the season. Likewise there was a tendency for the sugar percentage to be decreased less in U. S. 35/2, a high sugar selection, than in U. S. 22/3. However, this interaction was not significant.

## Summary and Conclusions

The effect of nitrogen application on petiole composition and yield and quality of sugar beets was studied under three widely varying fertility levels.

Where needed, nitrogen applications increased beet yields as much as 14 tons per acre and the sugar yields were increased from 1.72 tons to 3.73 tons by nitrogen application. There was a gradual decrease in sugar percentage with nitrogen application with the decrease becoming greater about the 160-pound nitrogen rate. At the Glud experiment where the zero nitrogen plots yielded 4.28 tons of sugar per acre, nitrogen had no significant effect on beet yield or sugar percentage.

Nitrogen application increased the beet yield and decreased the sugar percentage of both varieties of the Nitrogen x Variety experiment. The resultant sugar tonnage was increased by the first increment of nitrogen only. At the high rate of nitrogen application U. S. 35/2, a high sugar strain, showed a tendency toward higher sugar percentage and lower nitrate level than that of U. S. 22/3, but the interaction was not significant.

The nitrate-nitrogen content of sugar beet petioles was closely related to nitrogen application and degree of response. These preliminary results indicate that for optimum yields the nitrate in the petiole should be maintained above the critical level until about 11 to 12 weeks before harvest.

When high nitrates were found as late as 3 to 9 weeks before harvest the sugar percentages were decreased enough to overshadow any increase in beet yield. However, further study is necessary to establish critical levels

in relation to harvest time for a wider range of conditions in Imperial Valley. This type of information could be a valuable aid to growers in determining their nitrogen fertilization program for optimum sugar yields.

**ACKNOWLEDGMENT**

The authors are indebted to P. I. Rosenblatt for assistance in carrying out field experiments; to Charles Price, Section of Sugar Plant Investigations, for supplying seeds; to R. S. Ayers, Farm Adviser, Imperial County, for assistance in choosing experimental sites, and to the Holly Sugar Corporation, Carleton plant, for sugar and purity analysis.

## Literature Cited

(1) HADDOCK, J. L.
1953. Sugar beet yield and quality as affected by plant population, soil moisture condition, and fertilization. Utah Agricultural Experiment Station Bulletin 362.

(2) JOHNSON, C. M. and ULRICH, ALBERT
1950. Determination of nitrate in plant material. Analytical Chemistry. 22: 1526-1529.

(3) ULRICH, ALBERT
1950. Nitrogen fertilization of sugar beets in the Woodland area of California.
II: Effects upon the nitrate-nitrogen of petioles and its relationship to sugar production. Proc. Amer. Soc. Sug. Beet Tech. 6: 372-389.

(4) ULRICH, ALBERT
1948. Plant analysis as a guide to the nutrition of sugar beets in California. Proc. Amer. Soc. Sug. Beet Tech. 5: 364-377.

# The Effect of Fertilizer Treatments Upon Yield and Sugar Content of Sugar Beets at Garden City, Kansas[1]

CARL W. CARLSON AND ROY B. HERRING[2]

Many questions regarding fertilizer needs for sugar beets have not received a satisfactory answer. In the Garden City area most farmers are using fertilizer on sugar beets with little knowledge of what benefits they are receiving from it.

Many workers (1, 2, 3)[3] have reported that high rates of nitrogen fertilizer tend to reduce the sucrose percentage in the beets. If a farmer is to produce more sugar per acre, he must get a substantial increase in beet yields, if the above statement is true.

Chemical soil tests, plant analyses, or a combination of methods often are useful in diagnosing nutrient needs. According to certain workers (4, 6), a more generally applicable method of assessing the nutrient status is found in plant analysis, if the "critical" nutrient level for a given element and crop has been established previously by correlation studies. In this study the experimental technique of sampling and analyses proposed by Ulrich was used on three beet locations in an attempt to evaluate the nitrogen status of beet leaves on a series of three nitrogen treatments.

This study was conducted to examine the effectiveness of commercial fertilizers in increasing the yield of sugar per acre. The experiments were conducted in cooperation with the Garden City Sugar Company on farms in the Garden City area.

## Experimental Design and Procedure

Five fertilizer experiments, each located on farmers' fields, were conducted during 1952. The preparation of the land, planting, irrigation and cultivation were done by the farmers. The placement of the fertilizer, supervision of thinning, and harvesting were done by Station personnel. The design employed for each experiment was a randomized block comprising a factorial combination of three levels of nitrogen and phosphorus—0, 60, and 120 pounds of N and $P_2O_5$ per acre. An extra treatment receiving 120 pounds each of N and $P_2O_5$ and 60 pounds potash was added. The fertilizer treatments were replicated four times. Plot size was 6 rows wide and 50 feet long. The nitrogen was applied as ammonium sulfate and phosphate as treble-super phosphate. The fertilizer was banded 2 inches deep and 2 inches to the side of the seed after planting and before germination, using a belt fertilizer machine.

---

[1] Contribution No. 3, Garden City Branch Experiment Station, Kansas Agricultural Experiment Station, Manhattan. Published with the approval of the Director of the Kansas Agricultural Experiment Station.

[2] Formerly Assistant Agronomist, Kansas State College, now Soil Scientist, Western Section of Soil and Water Management, Soil and Water Conservation Research Branch, A.R.S., U.S.D.A., and Wyoming Agricultural Experiment Station, and Assistant Agronomist, Kansas State College, respectively.

[3] Numbers in parentheses refer to literature cited.

Soil samples were taken to an 8-inch depth prior to fertilization. Available phosphorus was determined by the sodium bicarbonate method as described by Olsen and others (5). The exchangeable potassium was extracted with neutral normal ammonium acetate and determined by means of a Perkins Elmer flame photometer. Organic carbon was determined by the Walkley and Black rapid titration method. Results of these analyses are shown in Table 1.

**Table 1.—Chemical Properties of Soils Included in Sugar Beet Fertility Studies.**

| Location | Available $P_2O_5$ Lbs./A. | pH 1 to 5 | Percent Organic Carbon | Available K Lbs./A. |
|---|---|---|---|---|
| Roth | 83.0 | 8.2 | 1.07 | 1,320 |
| Knipp | 82.5 | 7.9 | 0.94 | 1,460 |
| Gross | 56.8 | 8.7 | 0.79 | 1,620 |
| Brenner | 89.1 | 8.3 | 0.88 | 1,020 |
| Mayo | 8.3 | 8.4 | 0.83 | 880 |

Petiole samples, taken three times during the growing season, consisted of taking 30 leaves, selected at random, from 30 plants. Each petiole selected for analysis was from a leaf defined by Ulrich (8) as "a youngest mature leaf." The leaves were taken to the laboratory, washed, cut into 2-inch lengths and placed in the oven at 70° C. for 40 hours. Nitrate nitrogen and phosphate were determined by the method suggested by Ulrich (7).

Beets were harvested by taking five rod-row samples from each plot. Six beets were collected from each end of the plot for sugar analyses. The sugar analysis was made at the laboratory of the Garden City Sugar Company, Garden City, Kansas.

## Experiment Results

### Yield Response to Fertilizer

The yield of beets in tons per acre is shown in Table 2. Nitrogen fertilizer significantly increased yields on two locations, and phosphate fertilizer increased yields on one location. Two locations failed to respond to either nitrogen or phosphate fertilizer. Yields on the unfertilized plots ranged from 10.3 to 16.7 tons per acre. Yield increase from fertilizer on Brenner location was 7.6 tons per acre maximum and at the Mayo location fertilizer increased yields as much as 8.5 tons per acre. The yield increase on the Mayo location in the plots receiving potash fertilizer indicates that potassium may be low in this soil. As shown in Table 1, the exchangeable potassium in the soil from the Mayo farm is somewhat lower than that of soils from other locations.

### Sucrose Content as Related to Fertilizer Treatment.

The sucrose percentage in sugar beets at different nitrogen treatments is shown in Figure 1. The tons sugar produced per acre appears in Table 2.

At all locations, application of nitrogen tended to reduce the sucrose percentage. The reduction was great enough to be significant at three loca-

**Table 2.—Yield in Tons Per Acre of Roots and Sugar at Various Locations and Fertilizer Treatments.**

| Treatment | | | Roth | | Knipp | | Gross | | Brenner | | Mayo | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | $P_2O_5$ | $K_2O$ | Roots T/A | Sugar T/A | Roots T/A | Sugar T/A | Roots T/A | Sugar T/A | Roots T/A | Sugar T/A | Roots T/A | Sugar T/A |
| 0 | 0 | 0 | 16.7 | 2.39 | 13.4 | 2.05 | 10.3 | 1.61 | 13.8 | 2.32 | 12.6 | 1.65 |
| 0 | 60 | 0 | 16.3 | 2.89 | 12.7 | 1.91 | 9.9 | 1.51 | 15.8 | 2.56 | 16.0 | 2.10 |
| 0 | 120 | 0 | 14.7 | 1.95 | 12.5 | 1.92 | 10.6 | 1.66 | 13.7 | 2.25 | 16.8 | 2.22 |
| 60 | 0 | 0 | 16.2 | 2.01 | 13.4 | 1.92 | 12.4 | 1.85 | 19.0 | 3.18 | 13.3 | 1.53 |
| 60 | 60 | 0 | 15.9 | 2.14 | 15.2 | 2.09 | 11.7 | 1.55 | 17.8 | 2.95 | 14.3 | 1.85 |
| 60 | 120 | 0 | 15.9 | 2.07 | 15.5 | 2.14 | 11.5 | 1.61 | 19.7 | 3.25 | 15.8 | 1.95 |
| 120 | 0 | 0 | 15.6 | 1.88 | 14.3 | 1.86 | 10.8 | 1.43 | 21.3 | 3.40 | 13.6 | 1.60 |
| 120 | 60 | 0 | 16.3 | 1.95 | 15.8 | 2.06 | 11.5 | 1.49 | 21.4 | 3.38 | 15.8 | 1.94 |
| 120 | 120 | 0 | 18.1 | 2.14 | 16.5 | 2.40 | 12.4 | 1.57 | 20.1 | 3.33 | 18.3 | 2.22 |
| 120 | 120 | 60 | 14.7 | 1.72 | 16.1 | 2.15 | 11.4 | 1.51 | 20.5 | 3.27 | 21.1 | 2.65 |
| L.S.D. .01 | | | NS | 0.45 | | NS | NS | NS | 4.1 | 0.71 | 4.3 | 0.84 |
| L.S.D. .05 | | | | 0.33 | 2.4 | | | | 3.1 | 0.53 | 3.2 | 0.63 |

tions. The greatest reduction occurred in the Roth soil. Here the 60-pound nitrogen rate reduced the sugar content more than 2 percent of that of the phosphated check. The decreased sugar content resulted in a decrease of 635 pounds of sugar per acre on the Roth location. On the Knipp location the reduced sugar percentage resulted in the nitrogen fertilizer plots producing no more sugar than the untreated plots even though the nitrogen increased root yield by nearly 3 tons to the acre.

On the Brenner location the presence of nitrogen had no deleterious effect on the sugar content even though the yields of roots were increased by as much as 6 tons. The sugar content on the Mayo location was depressed in the presence of nitrogen fertilizer, but not significantly. On the Roth and Gross location no root yield response was obtained, but nitrogen fertilizer severely depressed the sucrose content of the beets.

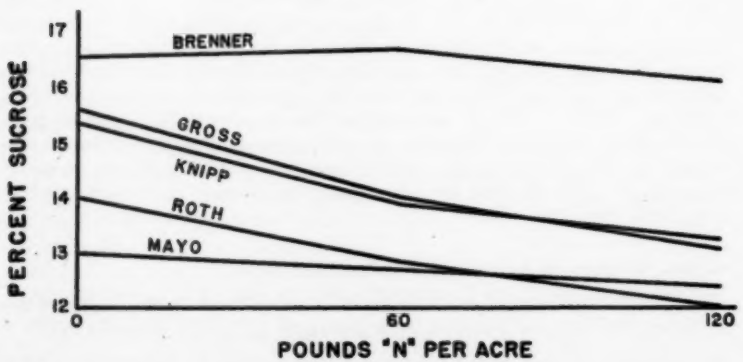


**Figure 1.—Sucrose content of beets at different nitrogen levels.**

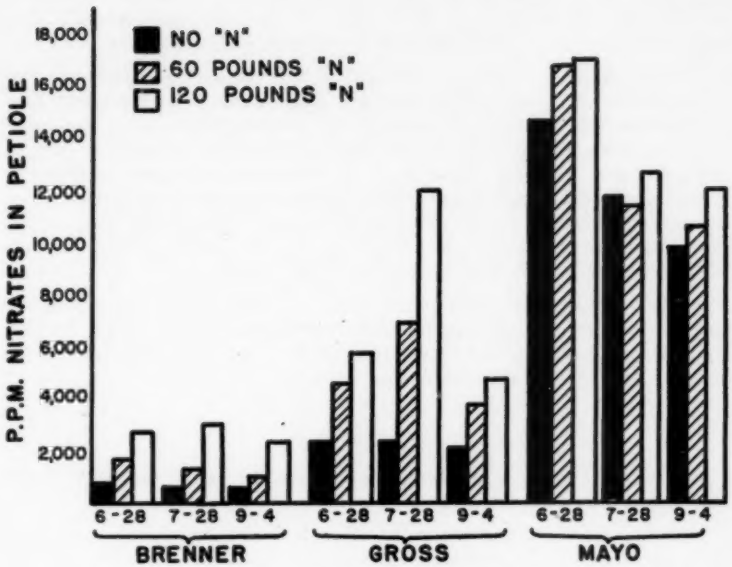


**Figure 2.—Nitrate-nitrogen in sugar beet petioles.**

It appears that phosphate fertilizer did not depress sucrose content. The presence of a combination of nitrogen and phosphate showed in general a smaller depressive effect than the same amount of nitrogen used alone.

**Nitrate and Phosphate in the Leaf Petiole.**

Results of an analysis made for nitrates in plant petioles are shown in Figure 2. The data show that the nitrogen applied as a fertilizer had a marked effect on the nitrate-nitrogen content of the beet petioles.

The petiole samples from the check plots varied a great deal in the nitrate content. The Brenner location responded to nitrogen fertilizer while the other two locations did not. The beets on the Gross farm showed a response early and late in the season.

The phosphate content was above 1,500 p.p.m. in petioles all during the season, even on the check plots. The Mayo location responded to phosphate fertilizer but the other two locations did not.

## Discussion

From the data given here it is evident that responses to nitrogen vary so markedly from field to field that it is impossible, even on the basis of field experiments, to arrive at general recommendations which will be

satisfactory for a high percentage of fields. Results show that either a deficiency or an excess of available soil and fertilizer nitrogen may have important economic consequences in sugar beet production.

When the nitrate-nitrogen content of beet petioles falls below 1,000 p.p.m., sugar beets can be expected to respond to nitrogen fertilizer. This critical level is in agreement with findings of other workers (4, 8). However, the levels at which quality is lowered does not agree with that of other workers. In this experiment the nitrate-nitrogen level was much higher on the Mayo location than on the Gross location. The sucrose percentage was lowered significantly on the Gross location but not on the Mayo location. The only explanation that can be offered is that the Gross location suffered severe hail damage early in August.

The sodium bicarbonate soil test for available phosphate appears to give an estimate of the supplemental requirements. The Mayo location had the lowest amount of available phosphate in the soil and was the only location that responded to phosphate fertilizer.

## Summary

A factorial design experiment was used in which three rates of nitrogen and phosphorus were included on 5 locations.

Results showed that nitrogen fertilizer decreased pounds sugar produced per acre significantly on one location and increased it significantly on another. Phosphate fertilizer increased pounds sugar produced significantly on one location.

Plant tissue tests proved to be a good indicator of which soils would respond to nitrogen fertilizer but not an indication of which soils would respond to phosphorus.

## Literature Cited

(1) BROWN, H. D., and IRVING, H.
1942. Plant-food elements in sugar beets throughout the growing season. Proc. Am. Soc. Sugar Beet Tech. 89-100.

(2) CARLSON, W. E.
1942. Mineral assimilation of sugar beets. Proc. Am. Soc. Sugar Beet Tech. 81-88.

(3) GARDNER, ROBERT, and ROBERTSON, D. W.
1942. The nitrogen requirements of sugar beets. Colo. Ag. Exp. Sta. Tech. Bul. 28.

(4) HADDOCK, JAY L.
1952. The nitrogen requirements of sugar beets. Proc. Am. Soc. Sugar Beet Tech. 159-165.

(5) OLSEN, STERLING R., COLE, C. V., WATANABE. FRANK, and DEAN, L. A.
Estimate of available phosphorus in soils by extraction with sodium bicarbonate. U. S. Dept. of Agr. Cir. (In Press).

(6) ULRICH, ALBERT
1946. Plant analysis as a guide in the fertilization of sugar beets. Proc. Am. Soc. Sugar Beet Tech. 88-95.

(7) ULRICH, ALBERT
1948. Diagnostic techniques for soils and crops. Chap. VI. Plant analysis: methods and interpretations of results. 157-198. American Potash Inst., Wash. 6, D. C.
1950. Critical nitrate levels of sugar beets estimated from analysis of petioles and blades with special reference to yield and sucrose concentration. Soil Sci. 60:291-309.

# The Application of Petiole Analyses to Sugar Beet Fertilization

D. Ririe, A. Ulrich, and F. J. Hills[1]

Nitrogen has been demonstrated to be the principal limiting fertilizer element in sugar beet production on most California soils (5)[2]. Phosphorus and potash have been shown to be insufficient for sugar beet needs on a lesser number of soils (5). A number of investigators (1, 2, 4, 7, 10, 11) have emphasized the critical aspects of nitrogen fertilization with respect to yield and sugar content of the crop. Through their work the reduction of yield resulting from an inadequate supply and the lowering of sugar content accompanying an oversupply has been demonstrated. It is essential then that time and rate of nitrogen application should be such that a good yield results with a minimal sucrose concentration reduction. The problem is further complicated by the fact that field needs vary widely in limited areas (1, 11). It has also been observed that the nitrogen fertilizer requirement of a single field may vary considerably in different seasons (6).

In answer to the problem of efficiently fertilizing sugar beets, with special reference to notrogen, Ulrich has proposed and refined techniques utilizing petiole analysis (7, 8, 9). The method consists of following the status of labile fractions of various essential plant nutrients by chemical analyses of dried petioles, plotting such data to obtain curves showing concentration changes with time, and fertilizing according to the interpretation of such curves. By means of pot and field tests critical concentration levels were found, below which plants were observed to develop deficiency symptoms and suffer yield reductions (7, 8, 9). It was suggested and demonstrated that the time for fertilization could be indicated by the rate at which the concentration of nutrients in the samples taken approached the established critical ranges (1, 8).

The purpose of the more recently completed experiments was to test and extend the usefulness of such techniques under field conditions.

## Methods and Procedure

Replicated field tests were set up with nitrogen rates varying over a rather wide range. Each plot consisted of four 2-row beds or six single-row beds, which were 60 feet long. Two hundred feet of row were harvested from each plot for yield determinations. Except for the check plots, a basic nitrogen rate was applied to all plots at thinning time or as a preplant application. As the need for supplemental applications was indicated by petiole analysis, more fertilizer was added by sidedressing at predetermined amounts. Whenever no approaching deficiencies were indicated by the analytical results, the supplemental applications were added at the latest practical date.

In one of the tests additional treatments were included in which all the nitrogen was applied at thinning time in amounts equivalent to that applied to corresponding plots receiving basic plus supplemental applica-

[1] Respectively, Assistant Agronomist, Associate Plant Physiologist, and Extension Agronomist, University of California, Davis.

[2] Numbers in parentheses refer to literature cited.

tions. The nitrogen was supplied as $NH_4NO_3$ or as $(NH_4)_2SO_4$. In addition to the plots receiving only nitrogen fertilizer, four tests included plots treated with phosphorus or both phosphorus and potassium, which were applied with a high rate of nitrogen. The rates applied are given in tables which follow. Both the $P_2O_5$ and $K_2O$ were applied before planting or at thinning time by sidedressing as treble superphosphate and $K_2SO_4$.

Petiole samples were collected periodically from each plot throughout the season and analyzed for $NO_3$-N. Certain of the samples were also analyzed for $PO_4$-P and K, but only for selected sampling times. At harvest time the beets were dug and yield and sucrose determinations made.

## Results

### Test 1

The harvest data for Trial 1 are given in Table 1 and three of the curves for petiole analyses are shown in Figure 1.

**Table 1.—Harvest Results. Trial No. 1, Davis, Yolo County, 1952.**

| Lbs. of N, $P_2O_5$ or $K_2O$ per acre | | Tons beets per acre | % sugar | Cwts. sugar per acre |
|---|---|---|---|---|
| May 31[1] | July 24 | | | |
| 0 | 0 | 21.1 | 15.9 | 66.8 |
| 80N | 0 | 23.6 | 15.5 | 72.8 |
| 80N | 40N | 25.9 | 15.1 | 78.2 |
| 80N | 80N | 28.5 | 14.7 | 84.0 |
| 80N | 160N | 30.4 | 14.0 | 84.8 |
| 200 $P_2O_5$, 80N | 160N | 29.7 | 13.6 | 80.6 |
| 200 $P_2O_5$, 200 $K_2O$ and 80N | 160N | 28.4 | 14.1 | 80.2 |
| Significant difference | (19:1) | 2.3 | 0.7 | 10.0 |
| | (99:1) | 3.1 | 0.9 | 13.4 |

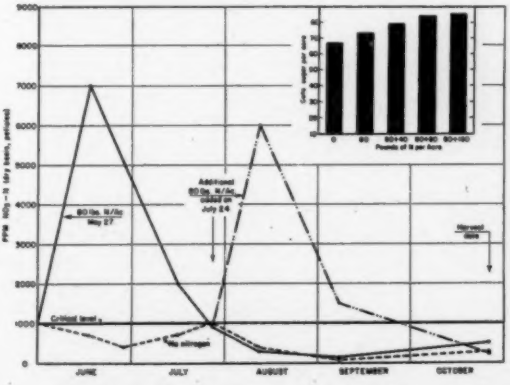


**Figure 1.—Effects fertilization on the nitrate-nitrogen content of sugar beet petioles. Trial No. 1, Davis, Yolo County, 1952.**

The curve indicated by the lower dashed line represents the check plots. In the case of this field the nitrogen level of the plants was below the critical concentration practically all season long when no fertilizer was applied. The $NO_3$-N content of the plants which received the 80-pound

per acre rate, as can be seen from the solid line curve, increased considerably after the nitrogen application, but declined rapidly as the season progressed and fell below the critical concentration three months prior to harvest. Both of these treatments resulted in lowered yields, which was anticipated from the petiole data. The remaining curve represents the analytical results from beets of the plots to which supplementary 80-pound nitrogen applications were made when petiole analysis showed an impending deficiency. From the data collected the best time for supplemental nitrogen application could have been predicted but not the amount to apply. At the highest supplemental rate no further significant yield increase was observed, nor was there any yield increase from phosphorus or potassium. The petiole P and K values were well above critical levels and no response was expected.

**Test 2**

In 1952-53 an experiment was conducted at the Meloland Field Station, Imperial County, California. The treatments, application dates, and yield data are reported in Table 2 and the petiole analysis curves for certain key treatments are found in Figure 2.

**Table 2.—Harvest Results. Trial No. 2, Meloland, 1952-53.**

| Lbs. of N per acre | | Tons beets per acre | % sugar | Cwts. sugar per acre |
|---|---|---|---|---|
| Nov. 5[1] | Jan. 29 | | | |
| 0 | 0 | 15.0 | 18.5 | 55.6 |
| 80 | 0 | 23.6 | 18.5 | 86.8 |
| 160 | 0 | 29.6 | 18.3 | 108.6 |
| 240 | 0 | 32.7 | 17.8 | 116.0 |
| 80 | 40 | 28.6 | 18.5 | 105.4 |
| 80 | 80 | 30.9 | 18.2 | 113.4 |
| 80 | 160 | 33.5 | 17.8 | 118.8 |
| Significant | (19:1) | 2.5 | 0.5 | 10.2 |
| difference | (99:1) | 3.4 | 0.6 | 13.6 |

[1] Thinning time. Planted September 25.

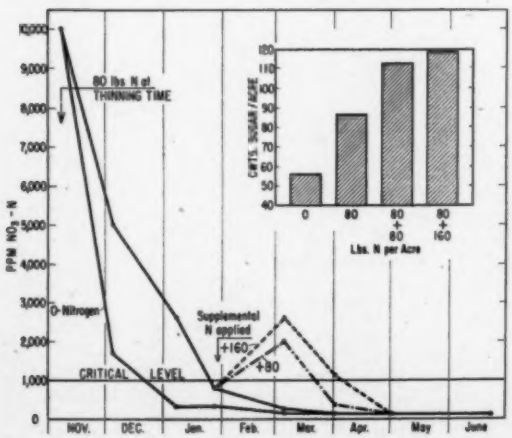


**Figure 2.—Effects of fertilization on $NO_3$-N content of sugar beet petioles. Trial No. 2, Meloland, Imperial County, 1952-53.**

In this test the beets responded to nitrogen rates up to 240 pounds per acre. There were no significant differences between the single and split applications at corresponding total nitrogen rates. The long periods of short nitrogen supply of those plots receiving no nitrogen or 80 pounds per acre at thinning time accounted for the yield reduction. When 80 and 160 pounds of nitrogen were applied as a supplement, the period of sufficient supply was extended 2 and 3 months respectively, resulting in yield increases.

**Test 3**

One of the tests was located on a field of very high nitrogen fertility. The yields of all plots, including check plots, were high and even at harvest time the $NO_3$-N concentration of the petioles was in excess of the critical level regardless of treatment. Consequently, there were no significant differences in yield due to nitrogen applications. Although petioles of beets which received supplemental nitrogen showed more nitrogen uptake, the difference between such treatments and the check was relatively small at all sampling dates. The data for this test are summarized in Table 3.

**Table 3.—Harvest Results. Trial No. 3, Santa Barbara County, 1953.**

| Lbs. of N, $P_2O_5$ or $K_2O$ per acre | | Tons beets per acre | % sugar | Cwts. sugar per acre[2] | $NO_3$-N content at harvest p.p.m. |
|---|---|---|---|---|---|
| Feb.[1] | May 30 | | | | |
| 0 | 0 | 30.8 | 15.2 | 93.6 | 5,730 |
| 80N | 0 | 33.8 | 14.9 | 100.8 | 5,460 |
| 80N | 80N | 33.8 | 14.2 | 96.8 | 6,530 |
| 80N | 160N | 30.6 | 14.5 | 88.8 | 7,150 |
| 80N, 200 $P_2O_5$ | 160N | 32.0 | 14.4 | 92.2 | 5,610 |
| 80N, 200 $P_2O_5$, 200 $K_2O$ | 160N | 33.0 | 14.3 | 94.4 | 6,180 |
| Significant difference | (19:1) | N.S. | N.S. | N.S. | N.S. |
| | (99:1) | N.S. | N.S. | N.S. | N.S. |

[1] Planting time.
[2] Calculated using treatment averages for tons beets per acre and percent sugar.

**Test 4**

Experiment 4 illustrates a case in which no response to added nitrogen was measured, even though such appeared likely. At the time of supplemental application the concentration of $NO_3$-N in the petioles was approaching the critical concentration. Even though supplemental nitrogen was applied June 5 and the field irrigated June 13 the $NO_3$-N content of the petioles did not increase appreciably. The petiole analyses correlated with the yield data, as indicated in Figure 3 and Table 4.

**Test 5**

In Tests 1, 2, 3, and 4 no response to phosphorus was observed. In Test 5, however, both nitrogen and phosphorus applications stimulated yields. The yield data, as reported in Table 5, show that nitrogen alone increased root yields about 7 tons per acre and when combined with adequate phosphorus another 7 ton per acre increase was measured.

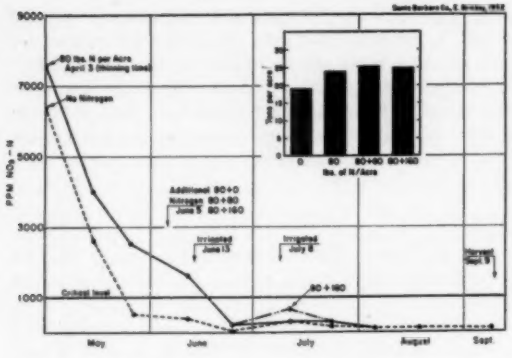


**Figure 3.—Effect of fertilization on $NO_3$-N content of sugar beet petioles. Trial No. 4, Santa Barbara County, 1952.**

**Table 4.—Harvest Results. Trial No. 4, Santa Barbara County, 1952.**

| Lbs. N, $P_2O_5$ and $K_2O$ per acre | | Tons beets per acre | % sugar | Cwts. sugar per acre | Beets harvest per 100' of row |
|---|---|---|---|---|---|
| April 3[1] | | | | | |
| 0 | 0 | 19.0 | 18.6 | 73.2 | 131 |
| 80N | 0 | 24.1 | 18.5 | 89.4 | 130 |
| 80N | 80N | 25.4 | 18.5 | 93.6 | 131 |
| 80N | 160N | 25.0 | 18.2 | 91.2 | 125 |
| 200 $P_2O_5$, 80N | 160N | 26.0 | 18.2 | 94.4 | 130 |
| 200 $K_2O$, 200 $P_2O_5$, 80N | 160N | 25.6 | 18.3 | 94.0 | 130 |
| Significant difference | (19:1) | 1.4 | N.S. | 4.6 | |
| | (99:1) | 1.9 | N.S. | 6.4 | |

[1] Thinning time.

**Table 5.—Harvest Results. Trial No. 5, Tulare County, 1952.**

| Lbs. N, $P_2O_5$ or $K_2O$ per acre | | Tons beets per acre | % sugar | Cwts. sugar per acre | Beets harvested per 100' of row |
|---|---|---|---|---|---|
| March 28[1] | June 27 | | | | |
| 0 | 0 | 14.5 | 17.8 | 51.4 | 230 |
| 80N | 0 | 18.1 | 17.2 | 62.4 | 235 |
| 80N | 40N | 20.3 | 17.0 | 68.8 | 256 |
| 80N | 80N | 19.4[2] | 15.8 | 61.2 | 250 |
| 80N | 160N | 22.0 | 15.3 | 67.4 | 242 |
| 80N, 200 $P_2O_5$ | 160N | 29.6 | 15.2 | 89.8 | 228 |
| 80N, 200 $P_2O_5$, 200 $K_2O$ | 160N | 27.6 | 15.3 | 85.0 | 239 |
| Significant difference | (19:1) | 2.4 | 0.9 | 8.8 | |
| | (99:1) | 3.2 | 1.2 | 11.8 | |

[1] Planting time. Fertilizer side-dressed 6 inches-8 inches from row and about 4 inches deep.

[2] This value is low because the yield of one of the plots in this treatment was exceptionally low (11.5 tons/acre).

Figure 4 shows the petiole analyses curves for $NO_3$-N and indicates an interesting effect of phosphorus on nitrate absorption. On May 30 the $NO_3$-N concentration was found to be higher on the plots which received

nitrogen plus phosphorus at planting time than those which received the same amount of nitrogen alone. On July 18 this appeared again in the samples taken soon after the supplementary nitrogen had been added. The converse phenomenon had been observed by Lorenz and Johnson (3) in which additions of ammonium sulfate increased the $PO_4$-P content of tomato foliage. In the latter case ammonium sulfate, because of its acid reaction in the soil, made more phosphorus available to the plants. In Trial 5 the greater absorption of nitrate in the presence of phosphorus may be due to faster root development or to increased root activity or to factors not now known.

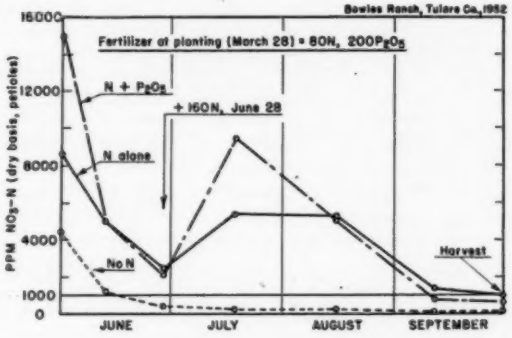


**Figure 4.—Effect of phosphorus fertilization of sugar beet petioles. Trial No. 5, Tulare County, 1952.**

Figure 5 shows the effect of phosphorus fertilization on the $PO_4$-P concentration of petioles. Both treatments plotted in this figure received the same amount of nitrogen (240 lbs. N/acre). The phosphate level of the plants which received no fertilizer phosphate ranged from 680 to 440 p.p.m. $PO_4$-P throughout the season, whereas the phosphate-fertilized plants always had a concentration of 1,600 p.p.m. $PO_4$-P or more. This difference accounted for the yield differences measured.

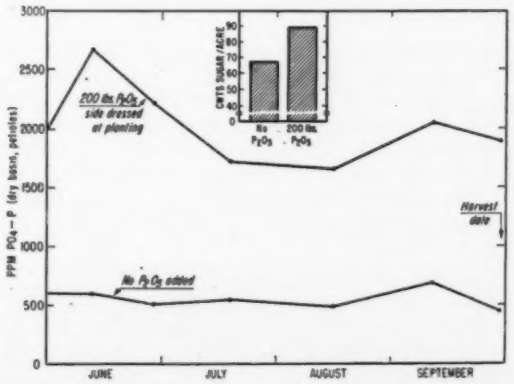


**Figure 5.—Effect of phosphorus fertilization on the $PO_4$-P concentration of sugar beet petioles. Trial No. 5, Tulare County, 1952.**

**Diagnosis of Sulfur Deficiency**

During the summer of 1953 a field was observed in which there was a large area of chlorotic sugar beets having symptoms indistinguishable from those produced by a nitrogen deficiency. Petiole analysis, however, showed that the affected beets were higher in nitrate-nitrogen than the more vigorous green beets. It was determined that there was no appreciable difference between good and poor beets in potassium or phosphate content, but that the sulfate content of the two varied widely as reported in Table 6. Although wide differences in the concentration of $SO_4$-S occurred in petioles as well as leaf blades, the latter appear to be better for diagnosis of possible sulfur deficiencies.

**Table 6.—Sugar Beet Leaf Analyses, Butte County, July 7, 1953.**

| | Leaf Analyses | | | | |
|---|---|---|---|---|---|
| | (petioles) | | | (blades) | (petioles) |
| Growth of sugar beets | $NO_3$-N (ppm) | $PO_4$-P (ppm) | K (%) | $SO_4$-S (ppm) | $SO_4$-S (ppm) |
| Vigorous | 2,520 | 2,120 | 3.15 | 1,880 | 530 |
| Poor | 9,000 | 2,900 | 3.80 | 155 | 85 |

After the analyses had been made, small strips of soil with the deficient beets were treated with ammonium nitrate, gypsum, and ammonium sulfate. The results of subsequent leaf analyses are found in Table 7.

**Table 7.—Sugar Beet Leaf Analyses, Butte County, August 11, 1953.**

| Treatments[1] | | | Leaf Analyses | |
|---|---|---|---|---|
| | Lbs. per acre | | | |
| Material | N | S | ppm $NO_3$-N (petioles) | ppm $SO_4$-S (blades) |
| Check | 0 | 0 | 640 | 750 |
| Am. nitrate | 200 | 0 | 7,600 | 295 |
| Gypsum | 0 | 484 | 580 | 13,600 |
| Am. Sulfate | 200 | 242 | 1,350 | 11,000 |

[1] Applied to single 4-row strips, July 20, 1953.

There was a great improvement in the appearance of sugar beets treated with $(NH_4)_2SO_4$. The deficiency symptoms disappeared, the leaves turned dark green, and there was a visible growth response. Petioles collected from these plants indicated that this growth response was associated with the absorption of $SO_4$-S. The addition of $NH_4NO_3$ did not correct the deficiency symptoms and the plants did not make the thrifty growth made by those receiving $(NH_4)_2SO_4$. When gypsum alone was added the plants readily absorbed $SO_4$-S but made no growth response; in fact, they made less growth than plants receiving $NH_4NO_3$.

Reasons for these divergent growth responses can be seen in the data presented in Table 7. When gypsum was added the sulfur deficiency was readily corrected, but almost immediately the plants became deficient in nitrogen and therefore little or no growth response would be expected. The addition of $NH_4NO_3$ kept the plants well supplied with nitrates but

they continued to be deficient in sulfur. $(NH_4)_2SO_4$ corrected the sulfur deficiency and also supplied the plants with sufficient nitrogen for good growth.

These observations illustrate that in many ins ances leaf analysis can be a very effective tool for rapid diagnoses of field problems.

## Discussion

These trials have provided case histories showing how leaf analysis might be used to improve practices in sugar beet fertilization. In each instance it was felt that such a technique could have led to better fertilization and a better understanding of the fertility problems of the fields studied.

Tests 1 and 2 illustrated that petiole analysis can be used to demonstrate impending nitrogen deficiencies and thereby act as a guide to time of application. In Test 2 there was apparently no advantage to applying the fertilizer in two applications rather than one. The point is raised, however, that at the beginning of the season there was no satisfactory way to predict with accuracy which of the rates applied would have been best. In fact, at mid-season petiole analysis could not be used to tell how much nitrogen to apply as indicated by the maximum response to 80 pounds of supplemental nitrogen in Test 1, whereas Test 2 required 160 pounds for best results. For such fields addition of an amount somewhat less than that considered adequate, with supplemental nitrogen applied when indicated by the analytical data, would appear most efficient. The amount of supplemental fertilizer to be added would depend on the length of growing season remaining and past experience with the field.

Test 3 represented a field in which certainly no supplemental nitrogen was needed or indicated by petiole analysis. In such fields, *i.e.*, those which may be judged to be high in fertility due to past history or the nature of the soil, it would probably be best to refrain from applying fertilizer until such time as the analyses indicated a need. In the particular field cited any fertilizer expenditure was wasted during that particular crop season.

If petiole analysis had not been used in Trial 4, a false conclusion might have been drawn due to the failure of beets to respond to supplemental nitrogen applications. The conclusion that the beets did not need more nitrogen would have been suggested from the yield data alone. Petiole analysis, however, showed that the plants did not absorb the supplementary nitrogen in amounts sufficient to affect the yields appreciably. Therefore, it may still be possible to obtain yield responses to nitrogen on this field if ways can be found to get supplementary nitrogen into the beets.

Test 5 demonstrated the relationship between both $NO_3$-N and $PO_4$-P concentration in sugar beet petioles and the growth of the plants. Leaf analyses of such a field would indicate the possibility of improving subsequent crops by phosphate fertilization. In all trials, except Number 5, phosphate and potassium analysis showed no indications of deficient supplies and, since no yield differences arose, the analytical data are not included.

**Summary**

The use of petiole analysis as a guide to sugar beet production was studied through a series of tests conducted in several California beet-growing districts. Petiole samples were taken periodically from check plots and from plots treated with predetermined basic fertilizer rates. Certain of the samples were analyzed for $NO_3$-N, $PO_4$-P, and K, and curves representing changes in plant content of the nutrients with time were constructed. In the case of nitrogen, supplemental applications were made when the curves indicated an approaching deficiency. When experiments were conducted on high fertility fields, in which no need of supplemental treatments was indicated, the same treatments were applied at the latest practical date.

The experiments demonstrated that petiole analysis can be a valuable aid in sugar beet fertilization on fields of high or low fertility. It was possible to predict from curves cases in which nitrogen responses could or could not be expected, and the time when supplemental applications should be made. It was also possible to use leaf analysis in improving phosphorus fertilization practices, and, as was pointed out in a case where a sulfur deficiency was found, to diagnose still other nutrient deficiencies.

**ACKNOWLEDGMENTS**

Farm Advisers Harwood Hall, Alan George, and Morton Morse, California Agricultural Extension Service, all rendered valuable assistance in conducting this work. The staff of the Meloland Field Station, Imperial County, California, also aided with tests conducted in that area. Sucrose analyses were made by the Holly Sugar Corporation, the Union Sugar Company, the Spreckels Sugar Company, and the American Crystal Sugar Company.

**Literature Cited**

(1) DUCKWORTH, W. R., and HILLS, F. J.
1952. Possibilities of improved nitrogen fertilization of sugar beets through the use of leaf analysis. Proc. Amer. Soc. Sugar Beet Tech. pages 252-254.

(2) HADDOCK, J. L.
1952. The nitrogen requirement of sugar beets. Proc. Amer. Soc. Sugar Beet Tech. 159-165.

(3) LORENZ, O. A., and JOHNSON, C. M.
1953. Nitrogen fertilization as related to the availability of phosphorus in certain California soils. Soil Science 75:119-129.

(4) PENDLETON, R. A., and ROBBINS, W. W.
1945. Fertilizers for sugar beets on some California soils. Calif. Agr. Exp. Sta. Bul. 694.

(5) ULRICH, A.
1944. Plant nutrient survey of sugar beets for 1944. Division of Plant Nutrition, Univ. of Calif., Berkeley.

(6) ULRICH, A.
1946. Plant analysis as a guide in the fertilization of sugar beets. Proc. Amer. Soc. Sugar Beet Tech. 88-95.

(7) ULRICH, A.
1948. Diagnostic techniques for soils and crops. Chap. VI. Plant analysis: methods and interpretations of results. 157-198. Amer. Potash Institute, Washington 6, D. C.

(8) ULRICH, A.
1948. Plant analysis as a guide to the nutrition of sugar beets. Proc. Amer. Soc. Sugar Beet Tech. 88-95.

(9) ULRICH, A.
1950. Critical nitrate levels of sugar beets estimated from analysis of petioles and blades with special reference to yield and sucrose concentration. Soil Sci. 69:291-309.

(10) ULRICH, A.
1950. Nitrogen fertilization of sugar beets in the Woodland area of California. II. Effects upon the nitrate-nitrogen of petioles and the relationship to sugar production. Proc. Amer. Soc. Sugar Beet Tech.

(11) WALKER, A. C., HAC, L. R., ULRICH, A., and HILLS, F. J.
1950. Nitrogen fertilization of sugar beets in the Woodland area of California. 1. Effects upon glutamic acid content, sucrose concentration and yield. Proc. Amer. Soc. Sugar Beet Tech. 362-371.

# Anhydrous Ammonia, the Effect of Time, Rate and Technique of its Application in the Production of Sugar Beets

F. H. Leavitt and R. L. Stier[1]

## Introduction

Though anhydrous ammonia has been used as a fertilizer on a commercial scale for more than twenty years its potentialities are just now becoming recognized throughout many of the eastern states. In consequence any discussion of its use would be incomplete without a brief description of the material itself as well as the methods of its use and the results obtained therefrom.

Anhydrous ammonia is composed of one part of nitrogen and three parts of hydrogen by volume. It is 82.25 percent nitrogen and 17.75 percent hydrogen by weight. At normal atmospheric temperature and pressure, ammonia is a colorless, pungent gas that boils at a minus 28° F. and freezes at a minus 107.9° F. Water has a great affinity for anhydrous ammonia, one volume at 32° F. absorbing as much as 1,020 volumes of ammonia. Soil particles have an even greater affinity for ammonia than has water, especially soils of a relatively high base exchange capacity.

Synthetic anhydrous ammonia was first produced here in the United States by the Mont Cenis modification of the Bosch-Haber process. In the process air was converted to liquid air by compressing and cooling. The liquid air was then fractionated into its component parts—nitrogen, oxygen, and the rare elements argon-zenon and krypton. Hydrogen was produced by the thermal decomposition of natural gas into its component parts, solid carbon and gaseous hydrogen. The purified nitrogen and hydrogen were then brought together in proper proportion under high temperature and pressure in the presence of a catalyst, with ammonia as the end product. More recently newer, simpler very high pressure processes have been developed which obtain the pure nitrogen and hydrogen by controlled burning of natural gas, the actual synthesis being carried out as in the Haber Bosch process.

## Role of Anhydrous Ammonia in Soil

When placed in the soil anhydrous ammonia enters into the base exchange complex and there is held tenaciously. In fact, the penetration of ammonia in soil is inversely proportional to the base exchange capacity. Once fixed in soil, ammonia is tightly held and is available for direct plant absorption. The tightly held ammonia which is not used directly by the plant undergoes conversion to nitrate nitrogen by bacterial action and then will move with the soil moisture into the continually changing root zone.

The application of ammonia is carried out by either of two means, Nitrogation Service[2] or Nitrojection Service[2]. The Nitrogation Service as

---

[1] Senior Agricultural Technologist, and Agricultural Technologist, respectively, Shell Chemical Company, San Francisco, California.

[2] Reg. U. S. Pat. Off.

the name suggests is the application of ammonia by its absorption in irrigation water and the subsequent proper distribution of that water. The Nitrojection Service is the application of ammonia by its direct injection into soil, no added water being necessary.

Now let us consider the use of ammonia as a nitrogen fertilizer for sugar beet production, particularly the effect of time, rate and method of applications on the production of sugar beets or, more specifically, the production of sugar.

### The Effect of Time of Application

The greatest increase of total sugar production has been shown when ammonia is applied in the early stages of plant growth. This is true whether application is by the Nitrogation or the Nitrojection Service.

With irrigation applications as shown in Table 1 a series of split applications was used. The first series reported includes two 75-pound per acre applications, a preplant application and an application at thinning time. The second series includes a 75-pound per acre application at thinning time and an application with the second regular irrigation.

Harvest data are reported in Table 1.

**Table 1.—The Effect of Time of Ammonia Application (Nitrogation Service).**

| Treatment | Woodland, California — Yolo Clay Loam Soil<br>Tons Beets/Acre | Lbs. Sugar/Acre |
|---|---|---|
| Check | 13.14 | 4,861.80 |
| 75 lb/A—Shell $NH_3$—Pre-irrigation and<br>75 lb/A—Shell $NH_3$—First regular irrigation | 15.28 | 5,011.84 |
| 75 lb/A—Shell $NH_3$—First regular irrigation<br>75 lb/A—Shell $NH_3$—Second regular irrigation | 13.78 | 4,657.64 |

It will be noted that sugar production increases were obtained with the first series of split applications and that while the second series of applications increased the total tonnage of beets produced, the total sugar produced was below that of the check. Later experience has shown that by delaying harvests a few weeks even the later-fertilized beets matured and sugared up as fully as did the early-fertilized beets.

With direct applications of ammonia, preplant applications may be made without the necessity of a preplant irrigation provided, of course, sufficient soil moisture is present.

In the direct injection experiments were included a preplant application of 75 pounds of ammonia per acre followed by a second application of 50 pounds per acre at thinning time to compare with a single preplant application of 125 pounds per acre. The harvest data from the experiment are reported in Table 2.

From the data in Table 2 it can be seen that no significant difference could be found between these two treatments and that very real increases of total sugar were realized with both treatments.

No applications late in the growing season were included in this series of experiments for earlier work had already proven them less effective.

Table 2.—The Effect of Time of Ammonia Application (Nitrojection Service)

| Salinas, California — Salinas Clay Loam Soil | | |
|---|---|---|
| Treatment | Tons Beets/Acre | Lbs. Sugar/Acre |
| Check | 14.81 | 5,589.29 |
| 75 lb/A—Shell $NH_3$—Preplant | | |
| 50 lb/A—Shell $NH_3$—After thinning | 20.43 | 8,662.32 |
| 125 lb/A—Shell $NH_3$—Single preplant application | 21.06 | 8,605.11 |

## The Effect of Rate of Application

Experiments designed to check the effect of rate of application were carried out in the Woodland area of California, using split applications of 100, 150 and 300 pounds of ammonia per acre. The harvest data are reported in Table 3.

Table 3.—The Effect of Rate of Ammonia Application (Nitrogation Service)

| Woodland, California — Yolo Loam Soil | | | |
|---|---|---|---|
| Treatment | Tons Beets/Acre | % Sugar | Lbs. Sugar/Acre |
| Check | 13.10 | 18.8 | 4,925.60 |
| 50 lb/A—Shell $NH_3$—May 12 and | | | |
| 50 lb/A—Shell $NH_3$—June 2 | 14.90 | 19.7 | 5,870.60 |
| 75 lb/A—Shell $NH_3$—As above | | | |
| 75 lb/A—Shell $NH_3$—As above | 16.05 | 19.7 | 6,323.70 |
| 150 lb/A—Shell $NH_3$—As above | | | |
| 150 lb/A—Shell $NH_3$—As above | 16.90 | 17.7 | 5,982.60 |

While applications were made somewhat later than desirable on this series of experiments due to late spring rains, significant tonnage and total sugar increases were shown with the 100- and 150-pound treatments. The 300-pound treatments showed greater total tonnage increases but reduced sugar. With the present winter carryover and spring harvest practices gaining in favor in California these heavier rates of applications may prove interesting in that longer maturing periods may be possible which should permit the absorption of higher amounts of ammonia, its assimilation—and the translocation of the formed sugar back into the storage root.

The above experimental data which led to our recommendation of 150 pounds of ammonia per acre for commercial applications has been substantiated in successive years in all of California's beet-producing areas.

Two rather unique experiments were conducted to test the effect of very high rates of application in the Woodland area of California on Yolo Clay loam. In these experiments applications up to 750 pounds of ammonia per acre were made. The first experiment applied as a side dressing shortly after thinning produced rather amazing results. The harvest data are reported in Table 4.

The interesting fact shown in Table 4 is that application rates as high as 750 pounds per acre do not damage beet crops even when applied as a side dressing after thinning time provided, of course, that the ammonia is properly placed.

Table 4.—The Effect of Rate of Ammonia Application (Nitrojection Service)

| Treatment | Woodland, California — Yolo Clay Loam Soil Tons Beets/Acre | % Sugar | Lbs. Sugar/Acre |
|---|---|---|---|
| Check | 27.9 | 15.4 | 8,593.20 |
| 150 lb. $NH_3$/A At thinning time | 36.1 | 13.0 | 9,386.00 |
| 450 lb. $NH_3$/A At thinning time | 37.8 | 13.7 | 10,357.20 |
| 750 lb. $NH_3$/A At thinning time | 35.6 | 14.3 | 10,181.60 |

A second experiment testing the effect of high rates of application was carried out the following year but differed from the first experiment in that the applications were made as preplant applications. The harvest data are reported in Table 5.

Table 5.—The Effect of Rate of Ammonia Application

| Treatment | Woodland, California — Yolo Clay Soil Tons Beets/Acre | % Sugar | Lbs. Sugar/Acre |
|---|---|---|---|
| Check | 21.20 | 19.50 | 8,268.00 |
| 250 lb/A—Shell $NH_3$—Preplant | 25.40 | 18.70 | 9,499.60 |
| 500 lb/A—Shell $NH_3$—Preplant | 23.50 | 17.80 | 8,366.00 |
| 750 lb/A—Shell $NH_3$—Preplant | 22.80 | 17.30 | 7,888.80 |

In this experiment it can be seen that tonnage was effectively increased with even the highest rates of application but a greater period for maturity was indicated with these higher application rates by the lower sugar at harvest time. Each increase in rate of application brought a decrease in sugar per acre by a lack of sugar translocation at the time of harvest.

## Top Weight Versus Root Weight Relationship

The time and rate of ammonia application markedly influence the ratio of top weight to root weight in sugar beets. This ratio change is shown in Table 6.

Table 6.—Top Weight Versus Root Weight Ratio

| Treatment | Woodland, California — Yolo Loam Soil (Nitrogation) Ave. Top Wt. | Ave. Root Wt. | Ratio |
|---|---|---|---|
| Check | .98 lbs. | 1.45 lbs. | 1—1.47 |
| 100 lbs./A—Shell $NH_3$—Preplant | 1.10 lbs. | 1.58 lbs. | 1—1.43 |
| 50 lbs./A—Shell $NH_3$—Preplant and 50 lbs./A after thinning | 1.15 lbs. | 1.54 lbs. | 1—1.34 |
| 75 lbs./A—Shell $NH_3$—Preplant and 75 lbs./A after thinning | 1.52lbs. | 1.87 lbs. | 1—1.22 |

In these data we have three comparisons: The first shows that fertilization increases the top growth in greater degree than it does the root growth. The second comparison shows that small split applications increase the top growth rates to a still greater degree than the root growth. Heavier split applications up to 150 pounds per acre increased top growth even more than do the lighter applications. The overall changes range from a 1 to 1.47 top-root ratio with the unfertilized beets to 1 to 1.22 with 150 pounds of ammonia in split application.

**The Technique of Ammonia Application**

In discussing the effect of time and rate of application of ammonia on the production of sugar beets we have referred frequently to Nitrogation Service and Nitrojection Service. These twin Shell patented processes are in reality two complementary methods of application. The Nitrogation Service is the method of applying ammonia by absorption in the irrigation stream and the subsequent proper distribution of the irrigation water. The Nitrojection Service is a method of direct injection of the ammonia into the soil without the use of irrigation. It may be practiced at any time of the year that soil may be cultivated.

The effectiveness of the Nitrogation Service method is governed to a large degree by the degree of care exercised in the control of the irrigation water. In areas where water is expensive and is carefully supervised, and a uniform irrigation is obtained, a very uniform application of ammonia follows. On the other hand, careless water supervision with excessive runoff will of course waste fertilizer.

Another factor of importance in the Nitrogation Service is the concentration of ammonia used. The greatest success has been achieved where concentrations of ammonia are not allowed to exceed 110 parts of ammonia per million parts of solution. This rate of applications will permit the application of 100 pounds of ammonia per acre with a 4-acre-inch irrigation. Application of more than 100 pounds per acre require the application of more than 4 acre inches of water for that irrigation or requires a split application with two successive early irrigations. At least one irrigation and preferrably two should follow the last application of ammonia at normal irrigation intervals to insure maximum utilization of the applied ammonia.

Simple metering equipment has been designed to control the flow of ammonia into the irrigation stream. It consists primarily of a flexible manifold to combine the flow from two or three ammonia cylinders, a single metering orifice, a device by which to determine the pressure of the ammonia in the tanks and a flexible hose to carry the ammonia from the metering orifice to the irrigation stream. With this simple meter the orifice may be changed to maintain uniform flows under changing temperature which causes changing pressure conditions.

The Nitrojection Service employs a similar metering principle as in the Nitrogation Service, but the ammonia is delivered underground instead of into irrigation water.

The actual injection is carried out by conducting the ammonia down the back of a specially designed cultivation shank and releasing it into the soil at a point 6 inches underground. Almost any type of cultivator equipment can be used for this work from row crop tractors for row crop application to large trailer injectors for open field preplant applications.

We mention that the shank is specially designed. It has a dual purpose: it ruptures the soil, increasing the internal pore space between soil particles, and it is self-sealing. Both features are important, the first because of the fact that a standard application of 100 pounds of ammonia per acre

puts underground about 2 cubic feet of ammonia vapor for each linear foot of shank travel; the second because the ammonia is under pressure and unless the shank channel seals behind the shank, quickly, ammonia will be lost from the soil into the air.

Two methods of application are practiced as preplant application for sugar beets. The first and most widely used is the application in the rough list before bed shaping in bed-planted beets. If the planting is two rows per bed the injection is made in the bed center directly between the positions where the two beet rows will be planted. If the planting is a single row per bed the placement is off center in the bed 4 inches or more from the point the row will be planted. This placement is necessary to insure that the tap root of the germinating beet will not grow immediately into an area of high nitrogen concentration and be injured; yet, it permits lateral roots to develop into the fringe areas of lower concentration, thereby assimilating nitrogen in the very early stages of growth.

Evidence of stimulation of the seedling at emergence time is not at all uncommon with both these methods of placement.

Where flat planting is practiced it is wise to make the ammonia injection at right angles to the direction the beet rows will be planted. This obviates the planting of an entire row—directly above the point of ammonia application, eliminating possible damage to an entire row if planted too close to the point of the injection.

In side dessing applications of ammonia by the Nitrojection method the injection is made as close to the growing beet as possible without mechanically loosening the beet in the soil or cutting more than 10 percent of the roots. Conditions usually permit the shank to travel 10 to 12 inches away from the beet row.

Application as close as possible to the growing beet using the above precautions is advisable in order that the beet roots develop in the fertilized area at an early date to permit early and complete utilization of the applied nitrogen.

## Summary

1. Anhydrous ammonia applied by either Nitrogation Service or Nitrojection Service has been demonstrated to be an effective fertilizer for sugar beets.

2. One-hundred and fifty pounds of ammonia per acre is an ideal rate of application, but rates up to 750 pounds per acre have been used without injury to growing plants.

3. Ammonia should be applied in the early stages of plant growth, i.e., preferably a preplant application or as a split preplant-thinning time application.

4. Ammonia applications increase production of both tonnage of beets and sugar and also increase top growth, decreasing the ratio of top weight to root weight from 1:1.47 in unfertilized beets to 1:1.22 in beets fertilizer at 150 pounds per acre in split application.

# Response of Yield-Type Versus Sugar-Type Sugar Beet Varieties to Soil Nitrogen Levels and Time of Harvest

F. J. Hills, L. M. Burtch, D. M. Holmberg and A. Ulrich[1]

Improvements in disease control and cultural practices have resulted in striking increases in the per acre production of beet sugar in California in the past two decades. This increase, however, has been due entirely to increased root yields as the trend in sucrose concentration has been steadily downward. An improvement in the sucrose concentration even though slight would mean a substantial gain for processor and farmer alike.

A promising, and highly worthwhile, approach to this problem is through the development of varieties with the ability to store greater concentrations of sugar. Such a variety, to be commercially acceptable, should also maintain disease resistance and other desirable characteristics, and be able to produce at least as much, and preferably more, sugar per acre than existing varieties. Attempts have been, and are being made, to develop "high sugar" varieties. At least one such variety, U .S. 35/2, has been released for commercial use in California.

The depressing effect of nitrogen on sugar storage has been demonstrated many times. In California, nitrogen is one of the principle variables among sugar beet fields (5)[2] (6). In at least one important beet growing area of California (Davis-Woodland area) the nitrogen nutrition of sugar beets has been demonstrated to be one of the main reasons for fluctuations in sugar concentration among beet fields (2) (3).

It would seem logical, therefore, to evaluate "sugar" varieties under varying nitrogen environments. Because varietal differences are likely to be small and difficult to measure such evaluations can best be made in factorial experiments where varieties can be grown close together at different nitrogen levels. This paper presents the results of two such experiments both conducted under essentially curly top-free conditions.

## Procedure

### General

In both experiments ammonium nitrate was used as the nitrogen source and was side-dressed on one side of each beet row shortly after thinning with a tractor-mounted precision applicator. The fertilizer rates used in both years supplied 0, 80, 160, and 240 pounds of N per acre. Plots were 8 rows wide and 70 feet long and the middle 60 feet of the 4 center rows were harvested. The beets in each plot were counted at harvest and four root samples, 15 to 25 beets each, were taken from each plot for sucrose concentration and tare determinations.

---

[1] Extension Agronomist, University of California, Davis; Agronomist, Spreckels Sugar Company, Sacramento; Farm Adviser, Woodland; and Associate Plant Physiologist, University of California, Berkeley, California, respectively.

[2] Numbers in parentheses refer to literature cited.

Petiole samples were collected at 3-week intervals throughout the growing season in both experiments to determine the nutritional status of the plants with respect to nitrogen, phosphorus and potassium.

Results were evaluated statistically by the method of analysis of variance (1).

**Woodland, 1950**

Two "sugar" varieties, SL 824 and SL 828, were compared with two standard varieties, U. S. 33 and U. S. 22/3, at the four levels of nitrogen. Subsequently SL 824 was released as U. S. 35/2 and for clarity will be designated as such in the Woodland experiment.

The 16 possible combinations of variety and nitrogen levels were arranged in a simple lattice with the basic design duplicated (4 replications) (1). Due to a nitrogen fertility gradient in the area selected for the experiment, this was an unfortunate choice of design. In the two replications where nitrogen levels were contiguous on variety blocks a good deal of precision as to variety comparisons was lost due to variations in initial fertility between the variety blocks. Where varieties were placed contiguously on nitrogen-level blocks highly precise variety and variety x nitrogen comparisons were possible. Only the data from these two replications, analyzed statistically as split plots, will be presented here.

**Davis, 1951**

U. S. 22/3 and U. S. 35/2 were the only varieties included in the second experiment. A third factor, time of harvest, was introduced as it was felt that this factor might have some influence on comparative varietal performance. A split plot design was used with nitrogen levels as the main plots laid out in a 4 x 4 Latin square. These plots were split for varieties and the variety plots split again for dates of harvest in strips across all 4 replications (1).

## Results

There was a marked growth response to nitrogen in the Woodland experiment. The optimum rate of nitrogen fertilization for this soil was about 160 pounds of N per acre. At harvest time a visible difference in top growth could be detected between beets which received 240 pounds of N as compared to plants which received the 160-pound rate. At harvest, petiole analyses indicated a low level of nitrate-nitrogen even in plants fertilized with 240 pounds of nitrogen per acre.

The field chosen for the Davis experiment turned out to be one of high fertility. There was very little or no growth response to nitrogen. Petiole analyses indicated that none of the non-fertilized plots became deficient in nitrogen until September. In this experiment the principal effect of nitrogen fertilization was to lower sucrose concentrations and thereby decrease total sugar production.

As a result of the difference in the initial nitrogen fertility of the two fields chosen for these experiments and the rates of nitrogen fertilization used it can be concluded that the two varieties U. S. 35/2 and U. S. 22/3 were compared over a wide range of nitrogen fertility.

In both experiments root counts at harvest indicated excellent stands and no important differences among treatments.

**Sucrose Concentration**

**Woodland.** All varieties reacted similarly to increasing levels of nitrogen with the possible exception of SL 828. This variety did not decrease in sucrose concentration at the 160-pound N rate as did the others. This probably accounts for the F value for the interaction of variety x nitrogen being close to the 5 percent level (Table 1). More data would be necessary before concluding that this was more than chance variation.

On the average U. S. 35/2 was the highest in sucrose concentration and U. S. 22/3 the lowest. U. S. 35/2 had higher sucrose concentration than U. S. 22/3 at all nitrogen levels. SL 828, on the average, was better than U. S. 22/3 but poorer than U. S. 35/2. U. S. 33 responded similarly to U. S. 22/3 but tended toward slightly greater sugar concentrations.

**Table 1.—Effect of Variety and Nitrogen on Sucrose Percentage of Sugar Beets at Woodland, California, 1950.**

| Lbs. N per acre | Varieties | | | | Nitrogen Means[3] |
|---|---|---|---|---|---|
| | U. S. 35/2[1] | SL 828 | U. S. 33 | U. S. 22/3 | |
| | Variety x Nitrogen Means[2] | | | | |
| 0 | 16.1 | 15.7 | 15.6 | 15.1 | 15.6 |
| 80 | 16.4 | 15.3 | 16.1 | 15.5 | 15.8 |
| 160 | 15.2 | 15.6 | 15.0 | 14.5 | 15.1 |
| 240 | 14.8 | 14.4 | 13.7 | 13.7 | 14.1 |
| Variety Means[4] | 15.6 | 15.2 | 15.1 | 14.7 | |

Significant differences at the 5% level: Between varieties at same nitrogen level—0.6; Variety means—0.3; Nitrogen means—1.5.

[1] SL 824
[2] Calculated F value for interaction = 2.55. F value required for significance at 5 percent level = 2.80.
[3] Significant at the 5 percent and 1 percent levels respectively.

**Table 2.—Effect of Variety, Nitrogen and Date of Harvest on Sucrose Percentage of Sugar Beets at Davis, California, 1951.**

| Lbs. N per acre | Varieties | | | | | | Varieties | | Nitrogen Means[2] |
|---|---|---|---|---|---|---|---|---|---|
| | U. S. 22/3 | | | U. S. 35/2 | | | U. S. 22/3 | U. S. 35/2 | |
| | Sept. 28 | Nov. 1 | Dec. 13 | Sept. 28 | Nov. 1 | Dec. 13 | | | |
| | Variety x Nitrogen x Date of Harvest Means[1] | | | | | | Variety x Nitrogen Means[1] | | |
| 0 | 13.5 | 14.6 | 14.7 | 14.3 | 15.1 | 15.3 | 14.3 | 14.9 | 14.6 |
| 80 | 12.7 | 13.0 | 13.5 | 13.9 | 14.4 | 14.2 | 13.1 | 14.2 | 13.6 |
| 160 | 12.1 | 12.9 | 13.4 | 12.8 | 13.4 | 14.3 | 12.8 | 13.5 | 13.2 |
| 240 | 11.7 | 13.1 | 12.7 | 12.4 | 12.9 | 13.5 | 12.5 | 12.9 | 12.7 |
| | Variety x Date of Harvest Means[1] | | | | | | Variety Means[2] | | |
| | 12.5 | 13.4 | 13.6 | 13.3 | 13.9 | 14.3 | 13.2 | 13.9 | |
| | Date of Harvest Means[2] | | | | | | | | |
| | Sept. 28 | Nov. 1 | Dec. 13 | | | | | | |
| | 12.9 | 13.7 | 14.0 | | | | | | |

Significant differences at the 5% level: Nitrogen means—1.2; Variety means—0.4; Date of harvest means—0.5.

[1] Interactions not significant at the 5 percent level.
[2] Significant at the 5 percent and 1 percent levels respectively.

**Davis.** Both varieties reacted to nitrogen and date of harvest in the same way. There were no interactions. U. S. 35/2 had a slightly higher sugar concentration at all nitrogen levels and dates of harvest. The sucrose concentrations of both varieties, at all nitrogen levels, increased with time. The greatest increase occurred during the month of October. The increase from November 1 to December 13 was small and probably not significant.

**Root Yields**

**Woodland.** U. S. 22/3, U. S. 33 and SL 828 all produced greater root yields than U. S. 35/2 at all nitrogen levels. U. S. 22/3 was the best root producer.

The significant variety x nitrogen interaction is principally due to the relatively greater response made by the sugar types to the first increment of nitrogen. Also, it appears that the tonnage types continued to respond relatively more to the 160-pound rate than did the sugar types.

**Table 3.—Effect of Variety and Nitrogen on Yield of Beet Roots (Tons per Acre) at Woodland, California, 1950.**

| Lbs. N per acre | Varieties | | | | Nitrogen Means[2] |
|---|---|---|---|---|---|
| | U. S. 35/2[1] | SL 828 | U. S. 33 | U. S. 22/3 | |
| | Variety x Nitrogen Means[2] | | | | |
| 0 | 13.2 | 15.1 | 16.7 | 18.0 | 15.7 |
| 80 | 18.3 | 20.9 | 20.0 | 20.1 | 19.9 |
| 160 | 19.3 | 21.1 | 21.6 | 23.4 | 21.3 |
| 240 | 18.7 | 21.5 | 19.8 | 22.6 | 20.7 |
| Variety Means[3] | 17.4 | 19.6 | 19.5 | 21.0 | |

Significant differences at the 5% level: Between varieties at the same nitrogen level—1.3; Between nitrogen levels for any variety—4.7; Nitrogen means—4.6; Variety means—0.7.

[1] SL 824
[2 3] Significant at the 5 percent and 1 percent levels respectively.

**Table 4.—Effect of Variety, Nitrogen and Date of Harvest on Yield of Beet Roots (Tons per Acre) at Davis, California, 1951.**

| Lbs. N per acre | Varieties | | | | | | Varieties | | Nitrogen Means[3] |
|---|---|---|---|---|---|---|---|---|---|
| | U. S. 22/3 | | | U. S. 35/2 | | | U. S. 22/3 | U. S. 35/2 | |
| | Sept. 28 | Nov. 1 | Dec. 13 | Sept. 28 | Nov. 1 | Dec. 13 | | | |
| | Variety x Nitrogen x Date of Harvest Means[1] | | | | | | Variety x Nitrogen Means[1] | | |
| 0 | 28.2 | 33.1 | 35.9 | 26.0 | 29.5 | 29.9 | 32.4 | 28.4 | 30.4 |
| 80 | 29.6 | 35.6 | 37.1 | 24.6 | 29.8 | 30.9 | 34.1 | 28.4 | 31.2 |
| 160 | 29.5 | 35.9 | 37.6 | 26.4 | 28.9 | 30.9 | 34.3 | 28.7 | 31.5 |
| 240 | 28.3 | 33.8 | 34.5 | 26.0 | 30.1 | 31.9 | 32.0 | 29.3 | 30.7 |
| | Variety x Date of Harvest Means[3] | | | | | | Variety Means[4] | | |
| | 28.9 | 34.4 | 36.3 | 25.7 | 29.6 | 30.9 | 33.2 | 28.7 | |
| | Date of Harvest Means[4] | | | | | | | | |
| | Sept. 28 | Nov. 1 | Dec. 13 | | | | | | |
| | 27.3 | 32.0 | 33.6 | | | | | | |

Significant differences at the 5% level: Between harvest dates for the same variety—1.0; Between varieties for the same harvest date—1.4; Variety means—1.1; Date of harvest means—1.1.

[1] Interactions not significant at the 5 percent level.
[2] No significant response to nitrogen.
[3 4] Significant at the 5 percent and 1 percent levels respectively.

**Davis.** U. S. 22/3 produced a greater root yield than U. S. 35/2 at all nitrogen levels and all harvest dates. There was a significant variety x date of harvest interaction with U. S. 22/3 making a relatively greater gain with time than U. S. 35/2. Considerably more growth occurred during the month of October than during the subsequent six-week period from November 1 to December 13.

### Gross Sugar Production

**Woodland.** There was a significant variety x nitrogen interaction due principally to the relatively greater response in root yield made by U. S. 35/2 to the first 80-pound nitrogen rate as compared to U. S. 22/3 and the failure of U. S. 35/2 to do as well at the higher nitrogen levels as did U. S. 22/3. The highly significant variety effect indicates the overall superiority of U. S. 22/3 to the other varieties.

**Table 5.—Effect of Variety and Nitrogen on Yield of Gross Sugar (Tons Per Acre) at Woodland, California, 1950.**

| Lbs. N per acre | Varieties | | | | Nitrogen Means[2] |
|---|---|---|---|---|---|
| | U. S. 35/2[1] | SL 828 | U. S. 33 | U. S. 22/3 | |
| | Variety x Nitrogen Means[2] | | | | |
| 0 | 2.12 | 2.36 | 2.58 | 2.69 | 2.43 |
| 80 | 2.99 | 3.20 | 3.21 | 3.10 | 3.12 |
| 160 | 2.92 | 3.28 | 3.23 | 3.40 | 3.20 |
| 240 | 2.78 | 3.08 | 2.71 | 3.09 | 2.91 |
| Variety Means[2] | 2.70 | 2.98 | 2.93 | 3.07 | |

Significant differences at the 5% level: Between varieties at the same nitrogen level—0.25; Between nitrogen levels for any variety—0.62; Variety means—0.12; Nitrogen means—0.58.

[1] SL 824.
[2] Significant at the 5 percent and 1 percent levels respectively.

**Table 6.—Effect of Variety, Nitrogen and Date of Harvest on Yield of Gross Sugar (Tons per Acre) at Davis, California, 1951.**

| Lbs. N per acre | Varieties | | | | | | Varieties | | Nitrogen Means[2] |
|---|---|---|---|---|---|---|---|---|---|
| | U. S. 22/3 | | | U. S. 35/2 | | | U. S. 22/3 | U. S. 35/2 | |
| | Sept. 28 | Nov. 1 | Dec. 13 | Sept. 28 | Nov. 1 | Dec. 13 | | | |
| | Variety x Nitrogen x Date of Harvest Means[1] | | | | | | Variety x Nitrogen Means[1] | | |
| 0 | 3.80 | 4.80 | 5.26 | 3.72 | 4.45 | 4.57 | 4.62 | 4.25 | 4.43 |
| 80 | 3.75 | 4.65 | 5.01 | 3.39 | 4.26 | 4.39 | 4.47 | 4.01 | 4.24 |
| 160 | 3.53 | 4.59 | 5.04 | 3.37 | 3.82 | 4.42 | 4.39 | 3.87 | 4.13 |
| 240 | 3.30 | 4.34 | 4.37 | 3.21 | 3.87 | 4.26 | 4.00 | 3.78 | 3.89 |
| | Variety x Date of Harvest Means[2] | | | | | | Variety Means[2] | | |
| | 3.60 | 4.59 | 4.92 | 3.42 | 4.10 | 4.41 | 4.37 | 3.98 | |
| | Date of Harvest Means[2] | | | | | | | | |
| | Sept. 28 | Nov. 1 | Dec. 13 | | | | | | |
| | 3.51 | 4.35 | 4.66 | | | | | | |

Significant differences at the 5% level: Nitrogen means—0.19; Between harvest dates for the same variety—0.17; Between varieties for the same date of harvest—0.18; Variety means—0.11; Date of harvest means—0.09.

[1] Interactions not significant at the 5 percent level.
[2] Significant at the 5 percent and 1 percent levels respectively.

**Davis.** U. S. 22/3 produced more sugar per acre at all harvest dates and all nitrogen levels than U. S. 35/2. A variety x date of harvest interaction occurred indicating that the sugar production advantage observed for U. S. 22/3 over U. S. 35/2 increased with time, particularly during the month of October, a period of rapid growth.

## Discussion

These experiments were designed primarily to learn more about possible variety x nitrogen interactions. While U. S. 22/3 was compared to the sugar type, U. S. 35/2, over a wide range of fertility levels in the two experiments more precise comparisons could have been made had the fertility levels all occurred in the same experiment. The use of an inefficient design in the Woodland experiment further reduced the precision with which these varieties might have been compared. Nevertheless, these data do point out that these varieties probably do respond somewhat differently to different levels of nitrogen fertility. When nitrogen is an important factor limiting growth the sugar-type appears to respond more rapidly to nitrogen fertilization. Skuderna and Doxtator (4) found the same sort of interaction in a study where a sugar type was compared to a tonnage-type variety at different levels of plant food (principally phosphorus). This indicates that varieties like U. S. 22/3 may be better nutrient foragers than sugar types such as U. S. 35/2. When a variety such as U. S. 35/2 is grown it appears to be even more important to provide sufficient fertility for maximum growth than it would be with a variety such as U. S. 22/3. More important, however, is the fact that under the conditions of these experiments U. S. 22/3 consistently produced more sugar regardless of nitrogen level or time of harvest than did U. S. 35/2 despite the fact that the latter variety consistently had a higher sucrose concentration.

On the basis of its performance in regard to total sugar production, a variety such as U. S. 35/2 appears to be less efficient photosynthetically than U. S. 22/3. The consistently higher sucrose concentration and lower root yield of U. S. 35/2 also indicates that sugar storage takes place at the expense of root and top growth.

## Summary

Field experiments were conducted near Davis, California, to determine how soil nitrogen levels and time of harvest might affect the performance of newly developed sugar-type varieties as compared to the more widely used tonnage types. The initial experiment compared the varieties SL 824 (U. S. 35/2), SL 828, U. S. 33 and U. S. 22/3 at 0, 80, 160 and 240 pounds of nitrogen per acre. Only U. S. 35/2 and U. S. 22/3 were compared in the second experiment. These two varieties were compared at the same four nitrogen levels and in addition at three dates of harvest (September 28, November 6, December 13).

Highly significant variety differences were observed in both experiments. The sugar-type varieties consistently contained higher sucrose concentrations but produced lower root yields and less gross sugar, regardless of nitrogen level or date of harvest, than did the tonnage types.

There was a significant variety x date of harvest interaction. U. S. 22/3 gained relatively more in root yield with increasing length of the fall growing period than did U. S. 35/2.

A significant variety x nitrogen interaction occurred with respect to root yield and sugar production when the varieties responded to nitrogen fertilization. This interaction indicates that U. S. 35/2 makes a relatively greater initial response to nitrogen than does U. S. 22/3 probably because U. S. 35/2 is a less efficient nutrient forager.

**ACKNOWLEDGMENT**

The authors would like to thank Melvin Zobel, formerly of the department of vegetable crops, University of California at Davis, for providing equipment for and assisting in the fertilizer applications; John McDougall of the Spreckels Sugar Company, Dr. A. C. Walker and Dr. Lucile Hac of the International Minerals and Chemical Corporation for assistance in carrying out the experiments; and Eldred Reel of Woodland and Carl Becker of Davis for providing the land for these experiments.

## Literature Cited

(1) COCHRAN, WILLIAM G. and COX, GERTRUDE M.
1950. Experimental Designs. John Wiley and Sons, Inc., New York.

(2) DUCKWORTH, W. R. and HILLS, F. J.
1952. Possibilities of improved nitrogen fertilization of sugar beets through the use of leaf analysis. Proc. Am. Soc. Sug. Beet Tech. 252-254.

(3) HILLS, F. J.
1950. Factors affecting sugar yields in the Woodland area. Spreckels Sugar Beet Bulletin XIV:42.

(4) SKUDERNA, A. W. and DOXTATOR, C. W.
1942. A study with sugar beets on two fertility levels of soil. Proc. Am. Soc. Sug. Beet Tech. 112-119.

(5) ULRICH, ALBERT
1943 and 1944. Plant nutrient survey of sugar beets. Mimeographed reports, Dept. of Plant Nutrition, Univ. of Calif., Berkeley, California.

(6) ULRICH, ALBERT
1950. Nitrogen fertilization of sugar beets in the Woodland area of California—II. Effects upon the nitrate-nitrogen of petioles and its relationship to sugar production. Proc. Am. Soc. Sug. Beet Tech. 372-389.

# Cropping and Fertilization Practices for the Production of Sugar Beets in Western Nebraska[1]

H. F. Rhoades and Lionel Harris[2]

Crop rotation experiments were conducted at the Scotts Bluff Experiment Station from 1912 to 1949. Scofield and Holden (10)[3] and Hastings (3) reported the results through 1934. The results for sugar beets during the entire period are summarized here.

Some of the specific objectives of this paper are: (a) to show the influence of cropping and manurial practices on soil properties and the production of sugar beets; (b) to show the relationships between soil properties and the sugar percentage of sugar beets; (c) to compare the influence of

**Table 1.—Some Rotations Including Sugar Beets at the Scotts Bluff Experiment Station. 1912-49.**

| Rotation No.[1] 1942-49 | Rotation No.[1] 1912-41 | Crop sequence and fertilization for period 1942-49.[2] |
|---|---|---|
| | | ROTATIONS WITHOUT ALFALFA |
| | | No Legume |
| 20 | 20 | Sugar beets, potatoes |
| 21 | 21 | (M) Sugar beets, potatoes |
| 20C | — | (N, P) Sugar beets, (N, P) potatoes |
| 35 | 30 | Sugar beets, barley, potatoes |
| 35B | 31 | (M) Sugar beets, barley, potatoes |
| 35C | — | (N, P) Sugar beets, barley, (N, P) potatoes |
| | | Field Beans Only Legume |
| 43B | — | (M) Sugar beets, barley, beans, potatoes |
| 43C | — | (N, P) Sugar beets, barley, beans, (N, P) potatoes |
| 67B | — | (M) Sugar beets, barley, beans, (M) sugar beets, barley, potatoes |
| 67C | — | (4/3 N, P) Sugar beets, (4/3 N) barley, (P) beans, (4/3 N, P) sugar beets, (4/3 N) barley, (4/3 N, P) potatoes. |
| | | ROTATIONS WITH ALFALFA |
| 41 | 40 | Sugar beets, barley (alf.), alfalfa, potatoes |
| 41B | — | (M) Sugar beets, barley (alf.), alfalfa, potatoes |
| 41C | — | (2 N, P) Sugar beets, barley (alf.), alfalfa, (P) potatoes |
| 66B | — | (M) Sugar beets, barley (alf.), alfalfa (2 yrs.), potatoes, beans |
| 66C | — | (2 N, P) Sugar beets, barley, (alf.), alfalfa (2 yrs.), potatoes, beans |
| 63 | 60 | Sugar beets, barley (alf.), alfalfa (3 yrs.), potatoes |
| 63B | 61 | (M) Sugar beets, barley (alf.), alfalfa (3 yrs.), potatoes |
| 63C | — | (2 N, P) Sugar beets, barley (alf.), alfalfa (3 yrs.), (P) potatoes |

[1] Where rotation numbers are given for both periods, there were only slight changes made in 1942. Where rotation numbers are given for the period 1942-49 only, old rotations were modified appreciably.

[2] M = 12 tons manure per acre applied for the crop indicated; N = 250 pounds ammonium sulfate or approximately 51 pounds nitrogen per acre; and P = 125 pounds superphosphate (45% $P_2O_5$) or approximately 56 pounds $P_2O_5$ per acre. Manure and commercial fertilizer were applied prior to the following crop mentioned. During the period 1942 to 1944, N = 125 pounds ammonium sulfate rather than 250 pounds.

[1] Contribution from the Nebraska Agricultural Experiment Station and the Soil and Water Conservation Research Branch, Agricultural Research Service of the U. S. Dept. of Agriculture. Published with the approval of the Director as Paper No. 645, Journal Series, Nebraska Agricultural Experiment Station.

[2] Agronomist, Nebraska Agricultural Experiment Station and Western Section of Soil and Water Management, Soil and Water Conservation Research Branch; and Associate Agronomist, Superintendent Scotts Bluff Experiment Station, Nebraska Agricultural Experiment Station and Western Section of Soil and Water Management, Soil and Water Conservation Research Branch, respectively.

[3] Numbers in parentheses refer to literature cited.

farm manure and commercial fertilizers for the production of sugar beets; and (d) to discuss the application of the results obtained at the Scotts Bluff Experiment Station to other soils in western Nebraska.

Detailed descriptions of the rotations and cultural practices used at the Scotts Bluff Experiment Station during the period from 1912 to 1941 have been reported (3, 10). Crop sequence and fertilization practices from 1942 to 1949 for the rotations emphasized here are reported in Table 1. Sugar beets were grown in 17 rotations during the period prior to 1942 and in 26 rotations during the period from 1942 to 1949.

### Relationships of Cropping and Manurial Practices to Nitrogen, Phosphorus and Potassium Levels in Tripp Soil

Total nitrogen content and nitrification rate of Tripp soil were materially influenced by the cropping and manurial practices followed from 1912 to 1941 (Table 2). Where neither manure was applied nor legume grown (Rotations 20 and 35), the nitrogen content of the soil after 30 years was approximately 36 percent lower than the nitrogen content of the virgin soil. Furthermore, the nitrogen level of the virgin soil was not maintained even where manure was applied at the rate of 12 tons per acre to one crop in two- and three-year rotations (Rotations 21 and 35B). The nitrogen level was almost maintained at the level of the virgin soil in Rotations 41 and 63 where alfalfa was grown one-half the time, and it was maintained in Rotation 63B where alfalfa was grown one-half the time and manure was applied at the rate of 12 tons per acre to one crop in the six-year rotation. Nitrification rate of the soil was affected more by cropping practice and manure application than was nitrogen percentage of the soil.

**Table 2.—Nitrogen, Phosphorus and Potassium Status of Tripp Soil to a Depth of 12 Inches After 30 Years of Cropping and Manurial Practice.[1]**

| Rotation Number | Nitrogen status[2] | | Phosphorus status[3] | | |
|---|---|---|---|---|---|
| | Total, | Nitrification rate, p.p.m. | Total, p.p.m. | Soluble at pH 5.0, p.p.m. | Exchangeable potassium,[2] |
| 1942-49 | % | $NO_3$-N | P | P | m.e./100 g. |
| **Virgin soil—sampled in 1912** | | | | | |
| — | 0.092 | — | — | — | 1.12 |
| **Two-year rotations—no legume** | | | | | |
| 20 | 0.059 | 9.7 | 361 | 14.4 | 1.26 |
| 21 | 0.079 | 14.9 | 423 | 27.9 | 1.91 |
| **Four-year rotation—alfalfa two years** | | | | | |
| 41 | 0.090 | 20.0 | — | — | — |
| **Three-year rotations—no legume** | | | | | |
| 35 | 0.059 | 9.8 | 359 | 9.6 | 1.22 |
| 35B | 0.081 | 16.5 | 421 | 25.9 | 2.12 |
| **Six-year rotations—alfalfa three years** | | | | | |
| 63 | 0.085 | 19.5 | 355 | 7.4 | 0.76 |
| 63B | 0.094 | 18.7 | 380 | 15.5 | 0.95 |

[1] Analyses on samples taken in 1941.
[2] Obtained from data reported by Kubota (5).
[3] Obtained from data reported by Yien (10).

Total and soluble phosphorus contents were greater in the soil from the manured than from the non-manured rotations, the differences being relatively greater for soluble than for total phosphorus. This effect of

manure application on soil phosphorus levels was obtained even though the removal of phosphorus by crops was greater in the manured than in the non-manured rotations (Tables 2 and 3). The relatively greater effect of manure on phosphorus level in the soil from non-legume than in the soil from legume rotations was associated with greater total amounts of manure applied during the 30-year period. Alfalfa in the cropping system increased the use of phosphorus by sugar beets and other crops. No doubt the alfalfa also used considerable phosphorus. Thus the inclusion of alfalfa in the cropping system may be expected to lower the available phosphorus level of the soil compared with cropping systems not including alfalfa or other legumes.

**Table 3.—Nitrogen and Phosphorus Contents of Sugar Beets at Harvest Time as Influenced by Cropping and Manurial Practices.**

| Rotation Number, 1942-49 | Percentage N (dry basis) in | | Percentage P (dry basis) in | | Pounds per acre in crop[2] | |
|---|---|---|---|---|---|---|
| | Tops[1] | Roots | Tops[1] | Roots | N | P |
| **IN 1935 AFTER 24 YEARS[3]** | | | | | | |
| **Two-year rotations—no legume** | | | | | | |
| 20 | 1.88 | 0.50 | 0.15 | 0.08 | 67 | 7.7 |
| 21 | 2.51 | 0.88 | 0.18 | 0.11 | 221 | 22.0 |
| **Four-year rotation—alfalfa two years** | | | | | | |
| 41 | 2.50 | 0.88 | 0.15 | 0.09 | 191 | 14.3 |
| **Three-year rotations—no legume** | | | | | | |
| 35 | 1.77 | 0.50 | 0.15 | 0.09 | 40 | 5.7 |
| 35B | 1.89 | 0.69 | 0.19 | 0.13 | 111 | 17.0 |
| **Six-year rotations—alfalfa three years** | | | | | | |
| 63 | 1.74 | 0.50 | 0.14 | 0.08 | 95 | 10.5 |
| 63B | 2.02 | 0.74 | 0.16 | 0.09 | 147 | 14.3 |
| **IN 1950 AFTER 39 YEARS[4]** | | | | | | |
| **Two-year rotations—no legume** | | | | | | |
| 20 | 1.66 | 0.46 | 0.15 | 0.08 | 54 | 6.3 |
| 21 | 2.49 | 0.65 | 0.20 | 0.23 | 154 | 28.1 |
| **Four-year rotation—alfalfa two years** | | | | | | |
| 41 | 2.23 | 0.65 | 0.18 | 0.08 | 119 | 11.3 |
| **Three-year rotations—no legume** | | | | | | |
| 35 | 1.64 | 0.38 | 0.14 | 0.09 | 46 | 6.1 |
| 35B | 2.03 | 0.61 | 0.29 | 0.13 | 113 | 19.6 |
| **Six-year rotations—alfalfa three years** | | | | | | |
| 63 | 2.25 | 0.72 | 0.11 | 0.07 | 170 | 11.1 |
| 63B | 2.61 | 0.87 | 0.17 | 0.09 | 265 | 20.5 |

[1] Does not include crowns in 1935; includes crowns in 1950.
[2] Total removed in tops, crowns, and roots.
[3] Data in 1935 obtained by J. C. Russel, M. D. Weldon, H. F. Rhoades and Lionel Harris, Nebraska Agricultural Experiment Station.
[4] Yields for 1949 used in calculating total nitrogen and phosphorus used per acre.

Exchangeable potassium was increased materially in Tripp soil by the application of manure in the non-legume rotations (Table 2). In contrast, where alfalfa was grown one-half the time there was a reduction in exchangeable potassium. Nevertheless, the levels of exchangeable potassium were well above the amounts needed to supply the crop even where alfalfa was grown.

Nitrogen and phosphorus levels in the soil due to cropping and manure application were also evaluated by determining percentages of nitrogen and phosphorus in various crops at harvest time in 1935 and 1950. Nitro-

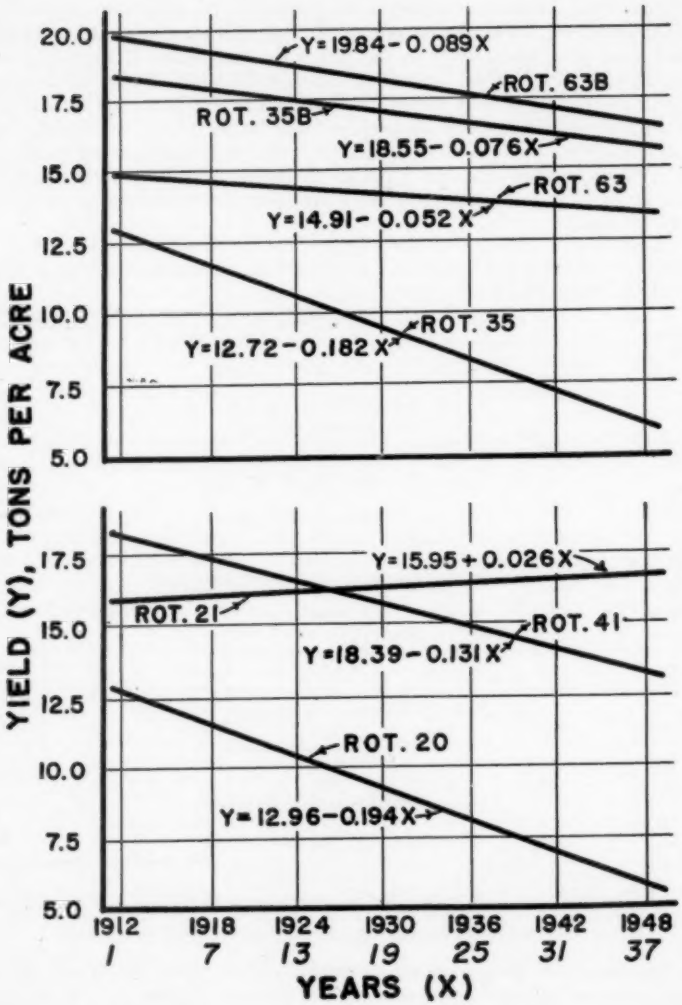


**Figure 1. Influence of alfalfa in the cropping system and manure application on the yields of sugar beet roots at the Scotts Bluff Experiment Station for a period of 38 years. Linear regression of yields (Y) and years in rotation (X).**

gen and phosphorus percentages in the tops and roots of sugar beets and the total amounts of these elements removed per acre in the crops were materially greater for the manured than for the non-manured rotations (Table 3). In general, nitrogen percentages in the tops and roots and the total amounts of nitrogen and phosphorus removed per acre by sugar beets were greater in the legume than in the non-legume rotations. However, phosphorus percentages in the tops and roots of sugar beets from the legume rotations were essentially the same as the percentages of that element in sugar beets from non-manured rotations without a legume.

## Yields of Sugar Beet Roots and Edible Beet Top Silage in Relation to Cropping and Manurial Practice

Yields of sugar beet roots and edible beet top silage were much greater in the rotations containing a legume or receiving manure than in the non-legume rotation without manure (Table 4). Nevertheless, the trends in yield of sugar beet roots were generally downward throughout the 38 years of study even in Rotation 63B with alfalfa three out of six years and a 12-ton application of manure for sugar beets (Figure 1). Linear regression lines depict the actual yield trends rather well for Rotations 21, 35B, 41, 63 and 63B. However, the abrupt decline in yields of sugar beets which occurred the first few years after 1912 is not shown accurately by the linear regression lines. It is believed that the decline in yield of sugar beet roots

**Table 4.—Influence of Cropping and Manurial Practice on Sugar Production and the Yield of Edible Silage by Sugar Beets.**

| Rotation Number, 1942-49 | Yield of roots, tons per acre | Sugar content, % | Gross yield of sugar, tons per acre | Edible beet top silage,[1] tons per acre |
|---|---|---|---|---|
| **MEAN OF VALUES FOR 1930 TO 1941[2]** | | | | |
| **Two-year rotations—no legume** | | | | |
| 20 | 7.8 | 17.6 | 1.37 | 2.0 |
| 21 | 16.8 | 17.1 | 2.87 | 4.7 |
| **Four-year rotation—alfalfa two years** | | | | |
| 41 | 15.0 | 16.3 | 2.44 | 3.9 |
| **Three-year rotations—no legume** | | | | |
| 35 | 7.8 | 18.0 | 1.40 | 2.0 |
| 35B | 16.6 | 18.0 | 2.99 | 4.5 |
| **Six-year rotations—alfalfa three years** | | | | |
| 63 | 13.4 | 15.9 | 2.13 | 3.6 |
| 63B | 17.3 | 15.8 | 2.73 | 5.0 |
| **MEAN OF VALUES FOR 1942 TO 1949** | | | | |
| **Two-year rotations—no legume** | | | | |
| 20 | 6.7 | 17.8 | 1.19 | 1.8 |
| 21 | 15.6 | 17.7 | 2.76 | 5.4 |
| **Four-year rotation—alfalfa two years** | | | | |
| 41 | 14.3 | 16.4 | 2.34 | 5.9 |
| **Three-year rotations—no legume** | | | | |
| 35 | 6.8 | 18.4 | 1.25 | 2.1 |
| 35B | 15.8 | 17.7 | 2.80 | 5.4 |
| **Six-year rotations—alfalfa three years** | | | | |
| 63 | 12.4 | 15.7 | 1.95 | 6.4 |
| 63B | 16.7 | 14.6 | 2.44 | 8.4 |

[1] Represents 78 percent of the green weight of tops as reported by Harris (2).
[2] Yield of sugar beet roots and sugar percentage for this period taken from circular by Nuckolls and Harris (9); yield of edible beet top silage for period 1939-41.

in the alfalfa rotations is due in part to a decline in the available phosphorus level in the soil (Table 2). Studies now underway should give more information on that point. Data reported by Schuster and Harris (9) suggest the possibility that an increased prevalence of root-knot nematode could account for a part of the decline in yields of sugar beets.

### Sugar Percentage and Sugar Production Due to Cropping and Manurial Practice

Nuckolls and Harris (7) pointed out that the inclusion of manure in cropping systems at the Scotts Bluff Experiment Station decreased sugar percentages of sugar beet roots slightly during the period from 1930 to 1941. In contrast, there was a much greater reduction in sugar percentage due to the inclusion of alfalfa in the cropping systems. Somewhat similar effects of manure application and alfalfa in the rotation of sugar percentages were obtained for the periods 1930 to 1941 and 1942 to 1949 (Table 4).

In view of the marked effects of manure applications and legume in the rotation on sugar percentage and on nitrogen level of the soil, a close relationship between the capacity of the soil to supply nitrogen and the sugar percentage of sugar beets grown on the soil is suggested. Such a relationship is further indicated by the negative correlations of percentage nitrogen and nitrification rate of the soil with sugar percentage of sugar beets for the rotations at the Scotts Bluff Experiment Station (Table 5). In addition, there was a highly significant correlation of —0.73 between nitrogen and sugar percentages of sugar beet roots sampled in 1935. The latter relationship is in agreement with results obtained by Haddock (1) and Hill (4).

**Table 5.—Correlation of Percentage Nitrogen and Nitrification Rate of Soil with Sugar Percentage of Sugar Beets. Rotation Experiments at the Scotts Bluff Experiment Station.**

| Correlation of soil property and sugar percentage of sugar beets | Correlation coefficient, r | |
|---|---|---|
| | 0 to 6 inch depth | 0 to 12 inch depth |
| Percentage nitrogen in the soil (1935 sampling) with: | | |
| Percentage sugar in 1935 | —0.58[1] | —0.54[1] |
| Mean percentage sugar for 1930 to 1941 | —0.71[2] | —0.68[2] |
| Percentage nitrogen in the soil (1941 sampling) with: | | |
| Percentage sugar in 1941 | —0.47[1] | —0.44 |
| Mean percentage sugar for 1930 to 1941 | —0.71[2] | —0.68[2] |
| Mean percentage sugar for 1942 to 1949 | —0.85[2] | —0.85[2] |
| Nitrification rate of soil (1941 sampling) with: | | |
| Percentage sugar in 1941 | —0.48[1] | —0.37 |
| Mean percentage sugar for 1930 to 1941 | —0.63[2] | —0.53[1] |
| Mean percentage sugar for 1942 to 1949 | —0.63[2] | —0.62[2] |

[1] Significant at the 5 percent level.
[2] Significant at the 1 percent level.

It is of interest to speculate on the reason for the relatively small effect of manure on sugar percentage of sugar beet roots compared with the effect of legume in the rotation even though both practices influenced the nitrogen level of the soil and the percentage nitrogen in sugar beet

roots to about the same degree. One suggestion comes from the relatively high phosphorus levels in the soil and the relatively high phosphorus percentage in sugar beet roots from the non-legume rotation receiving manure compared with the legume rotations. Possibly the manure supplied sufficient phosphorus for sugar beets to reduce the deleterious effect of added nitrogen. This was further suggested by the partial correlation coefficient of 0.45 in 1935 between percentage phosphorus and percentage sugar in sugar beets holding nitrogen percentage constant. Although the partial correlation coefficient of 0.45 was not significant at the 5 percent level (value of 0.47 required for significance), it seems reasonable to assume that the greater phosphorus supplied by manure might account in part at least for the relatively different effects of manure application and alfalfa in the cropping system on sugar percentage of sugar beets.

Maximum yields of sugar per acre were obtained in the non-legume rotation receiving manure (Table 4). That was due to a combination of moderate to high yields of roots with relatively high sugar percentages. The failure of the legume rotations to produce maximum yields of sugar was definitely associated with the unfavorable effects of legumes on sugar percentage. Because of this circumstance it should be desirable to grow sugar beets in the rotation as far away from the legume as possible.

### Comparison of Manure and Commercial Fertilizer for the Production of Sugar Beets

One of the important differences between the revised rotations and those conducted prior to 1942 was the inclusion of commercial fertilizer in the revised rotations. A combination of nitrogen and phosphorus fertilizers was applied in amounts approximately equal to the nitrogen but nearly double the amount of phosphorus supplied by manure in comparable rotations (Table 1). There was one important difference; all of the manure used in the rotations was applied for sugar beets, whereas the fertilizers were divided among two or more non-legume crops. The amount of phosphate applied for sugar beets was constant for all rotations; twice as much nitrogen was applied for sugar beets in the legume as in the non-legume rotations (Table 6).

There was some advantage of commercial fertilizer compared with manure in terms of root yields and sugar production by sugar beets in the rotations without alfalfa (Table 6). The reverse tended to be true in the alfalfa rotations. Similar sugar percentages and yields of edible beet top silage were obtained from manure and fertilizer applications. It is impossible to determine from the results obtained the individual effects of nitrogen and phosphorus on the production of sugar beets in the different rotations.

### Application of Results to Other Soils in Western Nebraska

To what extent will the influence of cropping and fertilization practices on soil properties and sugar beet production reported here for Tripp soil apply to other soils in western Nebraska? It seems likely that the same

practices would maintain soil nitrogen at a higher level in the finer-textured Mitchell and Minatare soils than in the Tripp soil. On the other hand, the nitrogen level would not likely be maintained as high by the same practices in the sandy Parshall and Bayard soils as in Tripp soil.

**Table 6.—Comparison of Manure and Commercial Fertilizer for the Production of Sugar Beets in Rotations with and without Alfalfa at the Scotts Bluff Experiment Station. 1945-1949.**

| Rotation No. | Nitrogen content of soil in 1941, % | Fertilization for sugar beets[1] | Mean yields 1945-49, tons per acre | | | Sugar content, % |
|---|---|---|---|---|---|---|
| | | | Roots | Gross Sugar | Edible Silage | |
| **ROTATIONS WITHOUT ALFALFA** | | | | | | |
| **No Legume** | | | | | | |
| 21 | 0.079 | Manure | 15.3 | 2.69 | 5.0 | 17.6 |
| 20C | 0.072 | N + P | 17.0 | 3.03 | 5.4 | 17.8 |
| 35B | 0.081 | Manure | 16.0 | 2.88 | 6.6 | 18.0 |
| 35C | 0.072 | N + P | 17.0 | 3.04 | 5.8 | 17.9 |
| **Field Beans Only Legume** | | | | | | |
| 43B | 0.065 | Manure | 14.6 | 2.76 | 4.9 | 18.9 |
| 43C | 0.063 | N + P | 15.5 | 2.82 | 5.5 | 18.2 |
| 67B[2] | 0.088 | Manure | 15.4 | 2.60 | 7.2 | 16.9 |
| 67C[2] | 0.091 | 4/3 N + P | 17.2 | 2.94 | 7.5 | 17.1 |
| **ROTATIONS WITH LEGUME** | | | | | | |
| 41B | 0.102 | Manure | 17.3 | 2.70 | 8.8 | 15.6 |
| 41C | 0.090 | 2 N + P | 17.4 | 2.70 | 9.4 | 15.5 |
| 66B | 0.096 | Manure | 18.3 | 2.78 | 9.8 | 15.2 |
| 66C | 0.087 | 2 N + P | 15.9 | 2.43 | 8.6 | 15.3 |
| 63B | 0.094 | Manure | 17.3 | 2.56 | 10.4 | 14.8 |
| 63C | 0.100 | 2 N + P | 16.3 | 2.43 | 9.6 | 14.9 |

[1] M = 12 tons manure per acre; N = 250 pounds of ammonium sulfate or approximately 51 pounds nitrogen per acre; and P= 125 pounds superphosphate (45% $P_2O_5$) or approximately 56 pounds $P_2O_5$ per acre.
[2] Mean of two crops of sugar beets per rotation.

There is evidence of a greater need of phosphorus by sugar beets grown on the calcareous Mitchell and Minatare soils than on the non-calcareous Tripp soil (6, 8). It seems likely that the Bayard and Parshall soils would be intermediate in phosphorus supply. Increases in yields of roots and sugar due to phosphate are much greater on the soils of medium-low fertility level than on soils of medium-high fertility level (Table 7). Potassium appears to be generally adequate for sugar beet production on most soils in western Nebraska. Differences in soils should be considered when judging the application of the results from the Scotts Bluff Experiment Station to other soils in the area.

## Summary

Crop rotation experiments were conducted at the Scotts Bluff Experiment Station from 1912 to 1949. The results obtained with sugar beets during the entire period were summarized.

1. There was a marked effect of cropping practice and manure application on soil properties, on yield of sugar beet roots, on sugar percentage of sugar beets, and on yield of edible silage.

Table 7.—Response of Sugar Beets to Application of Commercial Fertilizer to Tripp, Mitchell, and Minatare Soils in the North Platte Valley of Nebraska during 1947 and 1948.[1]

| Soil series | Number of experiments | No commercial fertilizer | Increase or decrease due to[2] | | | |
|---|---|---|---|---|---|---|
| | | | N | P | N + P | N + P + K |
| **MEDIUM-HIGH SOIL FERTILITY LEVEL[3]** | | | | | | |
| **Yield of roots, tons per acre** | | | | | | |
| Tripp | 3 | 16.4 | 0.7 | 0.0 | 0.5 | 0.8 |
| Mitchell | 3 | 16.0 | 0.0 | 0.7 | 0.7 | 1.0 |
| **Sugar content, %** | | | | | | |
| Tripp | 3 | 14.0 | —0.8 | 0.2 | —0.9 | —0.7 |
| Mitchell | 3 | 12.0 | —0.6 | 0.3 | —0.7 | —0.5 |
| **Gross yield of sugar, pounds per acre** | | | | | | |
| Tripp | 3 | 4,590 | —75 | 65 | —65 | —15 |
| Mitchell | 3 | 3,840 | —190 | 270 | —65 | 70 |
| **MEDIUM-LOW SOIL FERTILITY LEVEL[4]** | | | | | | |
| **Yield of roots, tons per acre** | | | | | | |
| Tripp | 4 | 9.2 | 1.2 | 1.0 | 2.0 | 2.1 |
| Mitchell | 5 | 8.1 | 1.0 | 2.3 | 2.5 | 3.2 |
| Minatare | 2 | 8.0 | 1.2 | 5.0 | 5.6 | 5.0 |
| **Sugar content, %** | | | | | | |
| Tripp | 4 | 12.6 | —0.1 | 0.4 | —0.1 | 0.0 |
| Mitchell | 5 | 12.0 | —0.8 | 0.2 | —0.6 | —0.8 |
| Minatare | 2 | 13.2 | —0.3 | 0.0 | —0.4 | —0.4 |
| **Gross yield of sugar, pounds per acre** | | | | | | |
| Tripp | 4 | 2,320 | 280 | 330 | 480 | 525 |
| Mitchell | 5 | 1,949 | 95 | 590 | 470 | 585 |
| Minatare | 2 | 2,110 | 265 | 1,320 | 1,385 | 1,220 |

[1] Experiments conducted cooperatively with the Great Western Sugar Co. (8).
[2] N = 65 pounds nitrogen as ammonium nitrate; P = 100 pounds $P_2O_5$ as superphosphate (45% $P_2O_5$); and K = pounds $K_2O$ as potassium chloride. Fertilizers were applied at the side of the row immediately after planting.
[3] Legumes included regularly in the cropping systems. Manure was applied for sugar beets and has been used frequently.
[4] Legumes included occasionally in the cropping systems. Little manure used.

2. Sugar percentage of sugar beets was negatively correlated with total nitrogen percentage of the soil, with nitrification rate of the soil, and with nitrogen percentage in the sugar beet roots.

3. There was some advantage of commercial fertilizer compared with manure in terms of root yields and sugar production by sugar beets in rotations without alfalfa. The reverse tended to be true in alfalfa rotations.

4. Greater yield responses by sugar beets from commercial fertilizers were obtained in western Nebraska on soils of medium-low fertility than on soils of medium-high fertility. The most outstanding response obtained was to phosphorus fertilizer on highly calcareous soils.

## Literature Cited

(1) HADDOCK, JAY L.
1953. Sugar beet yield and quality. Utah Agr. Expt. Sta. Bul. 362.

(2) HARRIS, LIONEL.
1948. Studies of beet-top silage production in the irrigated rotation experiments at the Scottsbluff, Nebraska, Field Station, 1942-1947. Proc. Am. Soc. Sugar Beet Tech. 1-8.

(3) HASTINGS, STEPHEN H.
1936. Irrigated crop rotation in western Nebraska, 1912-34. U. S. Dept. Agr. Tech. Bul. 512.

(4) HILL, KENNETH WILFORD.
1952. Effect of nitrogen supply on the sucrose percentage of sugar beets. Proc. Am. Soc. Sugar Beet Tech. 201-206.

(5) KUBOTA, JOE.
1944. Some chemical properties of an irrigated chestnut soil after thirty years of different cropping and manurial practices. Master's thesis, University of Nebraska.

(6) LYONS, E. S., RUSSEL, J. C. and RHOADES, H. F.
1944. Commercial fertilizers for the irrigated sections of western Nebraska. Nebr. Agr. Exp. Sta. Bul. 365.

(7) NUCKOLLS, S. B. and HARRIS, LIONEL.
1948. Effect of crop rotation and manure on the yield and quality of sugar beets, United States Scotts Bluff (Nebr.) Field Station, 1930-41. U. S. Dept. Agr. Circ. 779.

(8) RHOADES, H. F. and JOHNSON, WENDELL.
1949. Commercial fertilizers for sugar beets in Nebraska. Nebr. Outstate Testing Circ. 3.

(9) SCHUSTER, M. L. and HARRIS, LIONEL.
1952. Effects of crop rotation on the incidence of root-knot disease of sugar beets in western Nebraska. Proc. Am. Soc. Sugar Beet Tech. 511-518.

(10) SCOFIELD, CARL S. and HOLDEN, JAMES A.
1927. Irrigated crop rotations in western Nebraska. U. S. Dept. Agr. Tech. Bul. 2.

(11) YIEN, CHEN HWA.
1949. Influence of management practices on the form of phosphorus in an irrigated chestnut soil. Master's thesis, University of Nebraska.

# The Fertility Balance in a Ten-Year Sugar Beet Rotation After Forty-two Years of Cropping

S. DUBETZ[1]

## History of the Rotation

Crop rotations on irrigated land have been carried on at the Experimental Station, Lethbridge, Alberta, since 1910. Rotation "U," a 10-year rotation which was laid down on one acre plots in that year, is still in progress and is thought to be the oldest irrigated crop rotation in North America (1)[2].

This rotation originally consisted of six continuous years of alfalfa and one year each of oats, barley, potatoes, and spring wheat seeded down to alfalfa. Barnyard manure was applied at the rate of 12 tons per acre once in the rotation cycle. As conditions and crops changed with advancing years, it became necessary to make certain adjustments in the rotation. The first of these was the substitution of sugar beets for potatoes in 1923. By 1933 the yields of alfalfa had begun to decline, presumably because of phosphorus deficiency, and hence triple superphosphate (0-43-0) at the rate of 100 pounds per acre was applied to the south half of each plot for three of the ten crop years. The north half of each plot has never received any commercial fertilizers. In 1938 ammonium phosphate (11-48-0) was substituted for triple superphosphate.

By 1940 it was evident again that the yields were declining. Hence, the manurial application was increased to 30 tons in 1942. Since then, each plot has received 15 tons of manure twice in the rotation cycle.

Within recent years, bacterial wilt has reduced the yields of the fourth, fifth and sixth years of alfalfa to such an extent that it became necessary to revise the rotation. In 1951 the six continuous years of alfalfa were broken up into two 3-year periods with two other crop years intervening. No changes were made in the crops grown, and the fertility treatments have been maintained.

The crop sequence and fertilization plan of the rotation prior to the revision in 1951, together with the yields for the first 22-year period before fertilizer was applied and for the fertilized and unfertilized halves for the last 20-year period, are shown in Table 1.

The records of the yields of the crops, including the weights of straw from these plots, have made it possible to calculate the quantities of the three principal plant nutrients—nitrogen, phosphoric acid and potash—that were removed by these crops. This was done using the average amounts of these three constituents in the various crops. The amounts of these fertilizer constituents returned to the soil were calculated from periodic analyses of the barnyard manure and the guaranteed content of the commercial fertilizer applied. The fertility balances per acre per year for the three periods, for which the yield data are given in Table 1, are shown in Figures 1, 2 and 3.

---

[1] Agronomist, Experimental Station, Lethbridge, Alberta.
[2] Numbers in parentheses refer to literature cited.

Soil analyses have been carried out on samples taken from each plot at approximately 10-year intervals, the first samples being taken in 1911. Table 2 shows the results of recent analyses on stored remnants of the samples taken in 1911 and 1951.

**Table 1.—Crop Yields[1] Per Acre on Rotation "U" for the First 22-Year Period Before Commercial Fertilizer Was Applied and for the Unfertilized and Fertilized Halves for the Last 20-Year Period.**

| | | Experimental Station—Lethbridge, Alberta | | |
|---|---|---|---|---|
| Crop | Treatment | No Fertilizer 1911-1932 | No Fertilizer 1933-1952 | Fertilizer 1933-1952 |
| Alfalfa 1 | 100 lb. 11-48-0 | 2.29 | 2.60 | 3.00 |
| Alfalfa 2 | 15 tons manure | 3.46 | 2.62 | 4.10 |
| Alfalfa 3 | | 3.64 | 2.63 | 3.69 |
| Alfalfa 4 | 100 lb. 11-48-0 | 3.67 | 2.50 | 3.58 |
| Alfalfa 5 | | 3.77 | 1.98 | 2.80 |
| Alfalfa 6 | | 3.95 | 1.70 | 2.11 |
| Oats | | 92.8 | 100.0 | 104.2 |
| Barley | 15 tons manure | 57.5 | 72.5 | 74.2 |
| Sugar beets | 100 lb. 11-48-0 | 13.58[2] | 16.48 | 18.46 |
| Wheat seeded down to alfalfa | | 49.4 | 56.0 | 58.6 |

[1] Alfalfa and sugar beets in tons, cereal grains in bu. per acre.
[2] 10-year average.

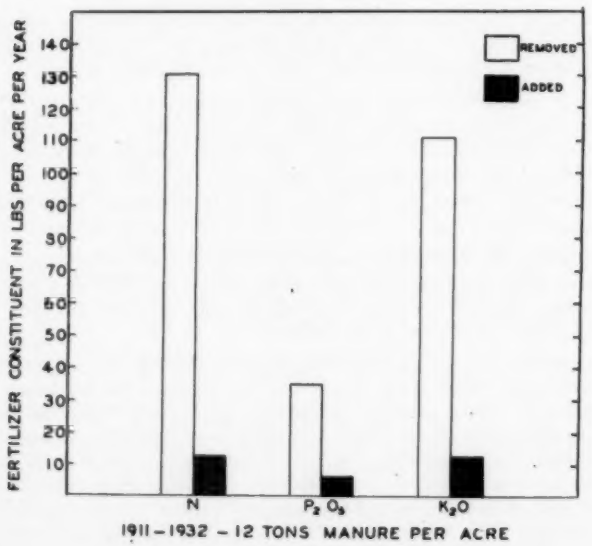


**Figure 1. Fertility balance on Rotation "U" for the first 22-year period 1911-1932, when barnyard manure was applied at 12 tons per acre once every ten years.**

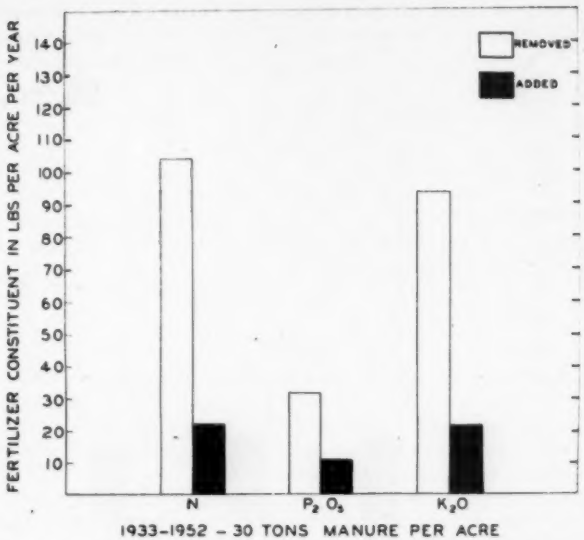


**Figure 2. Fertility balance on Rotation "U" for the 20-year period 1933-1952. In 1942 the manurial application was increased from 12 to 30 tons per acre per rotation cycle.**

**Table 2.—Analyses of Soil Samples[1] Taken from Rotation "U" in 1911 and 1951.**

| | N. (%) | | O.M. (%) | | $K_2O$ (%) | | P. (p.p.m.) | |
|---|---|---|---|---|---|---|---|---|
| | 1911 | 1951 | 1911 | 1951 | 1911 | 1951 | 1911 | 1951 |
| No fertilizer | 0.18 | 0.20 | 4.17 | 4.68 | .039 | .035 | 37.4 | 35.2 |
| Fertilizer | 0.18 | 0.20 | 4.17 | 4.82 | .039 | .035 | 37.4 | 39.7 |

**Method of Analysis**

N—Kjeldahl method.
OM—Loss on ignition—heating at 450° C. for 3 hours.
K—Exchangeable, using neutral normal ammonium acetate.
P—Soluble in 1 percent solution of $K_2CO_3$.

[1] Analyses were made by the Soil Chemistry Unit, Division of Chemistry, Science Service, Ottawa. Soil samples were taken from 0- to 6-inch depths.

## Nitrogen

Figures 1, 2 and 3 show a definite deficit in nitrogen for each of the three periods. However, the nitrogen that is returned to the soil by the alfalfa must be considered. Lyon and Buckman (2) state that an average crop of alfalfa fixes from 200 to 250 pounds of nitrogen per acre yearly. Since alfalfa is grown during six of the ten crop years, it may be assumed that an average of 120 to 150 pounds of nitrogen would be fixed every year for each acre of the rotation. This would more than balance any deficit, and it would seem that the nitrogen balance was at least maintained. The slightly higher percentages of nitrogen in 1951, as revealed by the soil analyses, substantiate this.

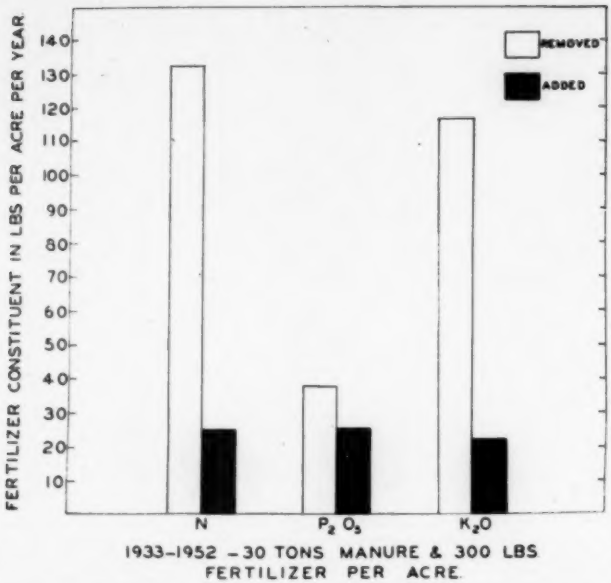


**Figure 3. Fertility balance on Rotation "U" for the 20-year period 1933-1952. In 1942 the manurial application was increased from 12 to 30 tons per acre per rotation cycle. In 1933 commercial fertilizer (0-43-0 from 1933 to 1937, 11-48-0 from 1938 to 1952) was applied at 100 pounds per acre for three of the ten crop years.**

### Organic Matter

Table 2 indicates that the organic matter content of the soil has increased since 1911. In the light of the heavy manure applications and the return of the crop residues from the high-yielding crops, it is reasonable to expect such a change.

### Phosphorus

A comparison of Figures 1, 2 and 3 shows that the greatest deficit of phosphoric acid occurred during the early period when only 12 tons of manure per cycle were added to the rotation and no phosphate fertilizer was used. Although high crop yields were obtained, the original fertility of the soil probably was reduced. This reduction is evidenced in Figure 2 and by the lower yields of the subsequent crops.

Increasing the manurial rate to 30 tons per acre per rotation cycle improved the phosphoric acid balance, but production of crops, especially alfalfa, was not as high in the early years of the rotation. The relatively higher average cereal crop yields, as compared with yields of alfalfa and

sugar beets, during the period following the increase in manurial rate may have occurred because the cereals are less sensitive to a mild deficiency of phosphorus than are alfalfa and sugar beets.

The highest yields of all crops were obtained on the plots which received commercial fertilizer along with the barnyard manure. Figure 3 shows the most favorable phosphoric acid balance. Results of the soil analyses show slightly higher amounts of phosphorus being made available in 1951 than in 1911. The reason for this may be due to the available form of phosphorus that is provided by the fertilizer. Nevertheless, a deficit in phosphorus does exist from year to year and, under the present fertilization program, it will be interesting to note the effect of additional cropping in future years on this condition.

### Potassium

The deficit of potassium follows closely the apparent deficit of nitrogen. Wyatt et al (3) report that the potassium content of soils in the Lethbridge area is between 1.25 and 1.75 percent. This may be represented as about 30,000 pounds of potassium per acre in the top six inches of soil. The soil analyses show a slight decrease in exchangeable potassium since 1911. Since the exchangeable potassium is believed to be in balance with non-exchangeable potassium and potassium in soil solution, a small decrease in one form may be an expression of a proportional decrease in the other forms. Although a decided yearly deficit in potassium exists, it seems to be of no immediate concern in view of the large amount present in the soil. No response to potash fertilizers has been obtained on soils in this area.

### Summary

The results from this long-term rotation show that a highly productive level of soil fertility can be maintained under irrigation with proper rotation, barnyard manure and commercial fertilizers. The three principal fertilizer elements—nitrogen, phosphorus and potassium—appear to be in fairly good balance in the soil after forty-two years of cropping. However, phosphorus and potassium are showing deficits. The immediate application of additional phosphorus may be warranted as a safeguard toward future reserves.

### Literature Cited

(1) HILL, K. W.
1951. Effects of forty years of cropping under irrigation. Sci. Agr. 31:349-357.

(2) LYON, T. L., and BUCKMAN, H. O.
1943. The nature and properties of soils. 386-387. The MacMillan Co., New York.

(3) WYATT, F. A., BOWSER, W. E., and ODYNSKY, W.
1939. Soil survey of Lethbridge and Pincher Creek sheets. Can. Dept. Agr. Bul. 32:64-65.

# Effects of Rotation on Sugar Beets in the Red River Valley

J. C. TANNER[1]

Sugar beet culture in the Red River Valley of Minnesota and North Dakota is relatively new. The East Grand Forks factory was completed in 1926, Moorhead in 1948, and Crookston will be completed in 1954. Acreage contracted for sugar beets was increased from 30,000 acres in 1944 to more than three times that acreage in 1954. This rapid expansion during the last ten years has led to one or more of the following questions by new growers: "What rotation practices are recommended for sugar beets? Why does the sugar company insist on summer fallowed land for beets? How can I clean up weedy land? Which green manure crop is the best?"

Answers to many of these questions have come from the experience and observations of the company's agricultural staff which pioneered sugar beet culture in the Red River Valley; but there was a lack of experimental results pertaining to rotation practices. To get accurate answers to these questions and also to keep abreast with the constantly changing economics of agriculture, it was decided in 1951 to set up a series of crop rotation plots on the company farm at East Grand Forks, Minnesota.

The soil type on which the rotation plots were located is Bearden silt loam, which is a silty clay loam that contains more sand and silt than the heavy Fargo clay soil of the Red River Valley. Sugar beets do well on either Bearden silt loam or Fargo clay soils. Both of these soils were rich in organic matter in their virgin state. The land on which the plots were located was purchased by the sugar company in 1950. This land had not been in a good soil building rotation; therefore, it was weedy and of below average fertility. Extreme care was taken to locate the plots in an area that was uniform as to soil type, fertility level, and was well drained. The entire plot area selected had been in the same crop each year, and had the same fertilizer history as far back as records could be obtained.

Considerable time and thought was used in planning the plot layout and rotations to be included. 100-foot x 200-foot rectangular plots, with 18-foot headlands on all sides of each plot, were agreed upon so that regular farm machinery could be used in caring for the crops. The 18-foot headland on all sides of each plot provided sufficient room to turn tractors and farm machinery without damaging adjacent plots. Each plot contained .46 of an acre with 18.50 acres in the entire test.

Eight rotations were selected. They ranged from what is considered to be the most desirable to the least desirable Red River Valley rotations that contain sugar beets. Four different green manure crops, of which three were legumes, were included. Two of the eight rotations did not include the summer fallow year. It may be found desirable to have additional rotations and replications in the future; if so, there is adequate land adjoining the plot area for future extension. The eight rotations selected are shown in Table 1.

---

[1] Agricultural Superintendent, American Crystal Sugar Company, Crookston, Minnesota.

**Table 1.—Rotations Included in Red River Valley Rotation Plots.**

| Rotation Number | Rotation | No. of Years in Rotation |
|---|---|---|
| 1 | Beets, Grain and Sweet Clover, Sweet Clover Summer Fallow | 3 |
| 2 | Beets, Grain, Summer Fallow | 3 |
| 3 | Beets, Grain, Buckwheat (Green Manure) Summer Fallow | 3 |
| 4 | Beets, Grain, Oats (Green Manure) Summer Fallow | 3 |
| 5 | Beets, Grain, Grain and Sweet Clover, Sweet Clover Summer Fallow | 4 |
| 6 | Beets, Grain, Grain, Grain | 4 |
| 7 | Beets, Grain, Grain, Potatoes | 4 |
| 8 | Beets, Grain, Grain and Alfalfa, Alfalfa Hay, Alfalfa Summer Fallow | 5 |

Each crop of each rotation in the test is planted each year; three plots for a three-year rotation; four plots for a four-year rotation, etc. Barley was selected for the grain crop in all rotations. Treble super phosphate (0-43-0) was applied to all sugar beet plots at the rate of 150 pounds per acre at planting time. Two hundred fifty pounds of 4-24-12 were applied to the potato plot at planting time. To date, this is the only commercial fertilizer applied in this test. The sugar beet tops and crowns were all worker into the soil after the beets were harvested. The barley straw was all left on the land. Normal tillage methods were followed as nearly as possible. The plots were all plowed in one direction to get away from dead furrows and to keep the area level for good drainage. The beets in all rotations were mechanically thinned by cross blocking and mechanically weeded with only enough hand hoeing done to keep the plots clean. Beet plots were harvested with an International sugar beet harvester.

The entire plot area was planted to potatoes in 1950 with the rotation test being laid out and plots planted to their respective crops in 1951. The only value of the yields taken in 1951 was to check differences due to soil variability. The1952 and 1953 crops were planted in their proper rotation sequence. We know that a test of this kind takes several years to produce statistically significant results, but using 1952 and 1953 yields and observations, certain trends are developing. The results to date have begun to answer with facts and figures such questions as: "Why does the company insist on summer fallow for beets?" and "What rotation will do to help clean up weedy land?"

**Table 2.—Effect of Rotation on Yields, and Cost of Hoeing Sugar Beets in 1952 and 1953.**

| | 1952 | | 1953 | | Mean | |
|---|---|---|---|---|---|---|
| Rotation Number | Tons Per Acre | Cost Per Acre to Hoe[1] | Tons Per Acre | Cost Per Acre to Hoe[1] | Tons Per Acre | Cost Per Acre to Hoe |
| 1 | 12.58 | $2.50 | 14.32 | $3.00 | 13.95 | $2.75 |
| 2 | 12.73 | 2.25 | 14.22 | 5.50 | 13.48 | 3.88 |
| 3 | 12.13 | 2.25 | 15.06 | 2.78 | 13.60 | 2.52 |
| 4 | 11.77 | 2.25 | 13.52 | 3.75 | 12.65 | 3.00 |
| 5 | 12.78 | 2.50 | 14.01 | 3.50 | 13.40 | 3.00 |
| 6 | 7.66 | 7.75 | 9.17 | 9.00 | 8.42 | 8.38 |
| 7 | 10.00 | 10.75 | 11.57 | 7.02 | 10.79 | 8.89 |
| 8 | 12.15 | 2.50 | 14.75 | 5.25 | 13.45 | 3.88 |

[1] Labor was paid 75 cents per hour for hoeing.

In Table 2, the yields of sugar beets in different rotations are shown. Also included in this table is the cost of hoeing each of the mechanically thinned beet plots.

The average yield where beets followed summer fallow was 13.41 tons per acre, which is 4.99 tons per acre more than where beets followed fall-plowed stubble land as in rotation 6. The yield of beets following potatoes was 2.62 tons per acre lower than where the beets were preceded by a year of summer fallow. In this area of limited rainfall, and no irrigation, it is essential to store up moisture in the summer fallow year for the following beet crop. In 1953, there was adequate spring and summer rainfall, while 1952 was below average in rainfall. This accounts for the generally higher yields in 1953. In the short period of two years, resultant differences between the various green manure crops and black summer fallow were not reflected in the beet yield. Only time will tell whether the plowing down of heavy leguminous green manure crops will raise the fertility level to the point where it will increase the yield over black summer fallow.

The results on the cost of hoeing clearly demonstrated the value of summer fallow as a weed control measure. In rotations where summer fallow preceded beets, the average cost to hoe was $3.17 per acre; while the average cost of hoeing beets that followed potatoes or grain was $8.64 per acre. The difference of $5.47 per acre represents a substantial saving as the cost of hoeing was more than cut in half by the use of summer fallowing.

Yield data were also kept on the barley plots and, using two years' results, no differences between rotations was recorded. However, it was found that the barley plots which followed beets were almost free of weeds, especially wild oats, while the barley plots which did not follow beets were badly infested with wild oats.

In addition to keeping yield and cost data on all plots, records were kept on the amount and analysis of various green manure crops plowed down. Samples were dug from each green manure crop just before it was plowed. Care was taken to get all of the roots possible from each green manure. These samples were weighed green, and turned over to our laboratory for analysis. The total amount of nitrogen, phosphorus ($P_2O_5$) and potassium ($K_2O$) being returned by the various green manures was determined. With this program, we are attempting to get an accurate answer to the question, "Which green manure crop is the best?" Table 3 gives the 1952 and 1953 results on the analysis of green manure crops. Calculations were made, placing the amounts of N, $P_2O_5$ and $K_2O$ on an acre basis.

## Summary

Results obtained so far indicate that sweet clover green manure returns the highest tonnage of organic matter to the soil. However, in rotation studies a period of two years is a very short time, and it would be hazardous to attempt to draw definite conclusions. This test is being continued and further results will be reported at a future date.

**Table 3.—Analysis of Green Manure Crops.**

| | Green Wt. Per Acre | | Moisture at 70 Degrees C. | | Pounds N Per Acre | | Pounds $P_2O_5$ Per Acre | | Pounds $K_2O$ Per Acre | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1952 | 1953 | 1952 | 1953 | 1952 | 1953 | 1952 | 1953 | 1952 | 1953 |
| **Alfalfa** | | | | | | | | | | |
| Roots | 6,305 | 7,587 | 50.88 | 58.58 | 63.2 | 67.4 | 9.7 | 3.9 | 24.9 | 22.7 |
| Tops | 9,258 | 10,516 | 64.99 | 75.22 | 93.0 | 72.5 | 15.5 | 4.6 | 67.9 | 61.1 |
| Total | 15,563 | 18,103 | | | 156.2 | 139.9 | 25.2 | 8.5 | 92.8 | 83.8 |
| **Sweet Clover** | | | | | | | | | | |
| Roots | 5,787 | 8,787 | 76.91 | 79.88 | 19.0 | 37.1 | 4.7 | 2.6 | 20.1 | 39.1 |
| Tops | 24,687 | 41,247 | 76.42 | 79.58 | 117.5 | 153.4 | 40.9 | 14.5 | 155.8 | 230.9 |
| Total | 30,474 | 50,034 | | | 136.5 | 190.5 | 45.6 | 17.1 | 175.9 | 270.0 |
| **Oats** | | | | | | | | | | |
| Roots | 2,587 | 1,633 | 76.59 | 70.29 | 4.6 | 5.7 | 1.6 | .7 | 7.8 | 4.9 |
| Tops | 15,616 | 18,246 | 69.30 | 80.26 | 62.3 | 50.4 | 10.9 | 15.4 | 73.1 | 98.8 |
| Total | 18,203 | 19,879 | | | 66.9 | 56.1 | 12.5 | 16.1 | 80.9 | 103.7 |
| **Buckwheat**[1] | | | | | | | | | | |
| Roots | 1,710 | | 76.46 | | 2.4 | | 1.7 | | 4.7 | |
| Tops | 13,718 | | 84.43 | | 31.3 | | 8.6 | | 47.4 | |
| Total | 15,428 | | | | 33.7 | | 10.3 | | 52.1 | |

[1] Buckwheat crop froze out in 1953.

# Preliminary Comparison of the Effects of Leguminous and Non-Leguminous Green Manures on Sugar Beet Production

W. A. Williams, D. Ririe, H. L. Hall and F. J. Hills[1]

The use of green manure crops has been a common practice in California agriculture since 1900 (2)[2]. However, information developed in controlled experiments relative to their value and the nature of their effects on soils and subsequent crops is limited. This is in large part due to the wide variation in soil conditions, climate and cropping sequences which limit the application of results determined under a particular set of circumstances.

The field experiment discussed in this paper is the first of a series of tests which are designed to evaluate the influence of various green manure crops on the growth, nutrition and yield of several field crops and accompanying physical and chemical changes in the soil, and disease and pest effects. The sugar beet was chosen as the test crop in this preliminary experiment because it is a crop which is very sensitive to the level of soil fertility and to soil structure. A winter legume and a non-legume were compared with fallow at two levels of nitrogen fertilization in a split plot design with fertilizer levels as the main plot treatments.

## Procedure

The experiment was established on Yolo sandy loam near Santa Maria, California, following a crop of potatoes. Six replications of strips 20 feet wide of Hero barley, purple vetch (*Vicia atropurpurea* Desf.), and a mixture of barley and vetch were planted across a small field on September 14, 1951, and sprinkled up. The seeding rates in pounds per acre were barley 80, purple vetch 45, and barley and vetch 10 and 40 respectively. The barley and vetch crops were turned under to a depth of 10 inches with moldboard plows after being rolled down on January 29, 1952, and sugar beets were planted February 5, 1952. At thinning time, April 23, 600 pounds per acre of ammonium sulfate were applied to three of the replications. Petiole samples were collected from the plots periodically and analyzed for nitrate-nitrogen, phosphate-phosphorus, and potassium by the methods developed by Ulrich and Hills (4, 5).

The beets were harvested September 10, 1952, with two double row beds 100 feet long being taken from each plot for yield. The effects of the treatments on water penetration were measured by taking successive readings on the heads of water in six single ring infiltrometers placed in each plot.

## Results and Discussion

Just prior to turning under the green manure crops, strips were cut to determine the amount of organic matter produced and its nutrient content.

---

[1] Assistant Agronomists, Farm Adviser, and Extension Specialist in Agronomy, University of California, respectively.

[2] Numbers in parentheses refer to literature cited.

The shoot length of the vetch was about 30 inches, and it was in the vegetative stage with a nitrogen content of 3.9 percent (Table 1). The barley averaged 38 inches in height and was in the early milk stage with a nitrogen content of 1.2 percent. The barley produced the most green weight; the vetch produced a little more than half as much. The vetch, however, contributed almost twice as much nitrogen to the soil in the top growth as did the barley. The barley and vetch mixture was intermediate for both green manure and nitrogen production. It contained 31 percent vetch and 69 percent barley with an average nitrogen content of 2.2 percent.

**Table 1.—Dry Matter Production, Nitrogen Content, and Amount of Nitrogen Turned Under in Green Manure.**

| Treatment | Dry Matter Turned Under Lbs./Acre | Nitrogen Content % | Nitrogen Turned Under Lbs./Acre |
|---|---|---|---|
| Fallow | 0 | — | 0 |
| Barley | 4,950 | 1.2 | 62 |
| Barley and vetch | 3,690 | 2.2 | 87 |
| Vetch | 2,620 | 3.9 | 115 |
| L.S.D. 5% | 870 | 0.3 | 23 |

Differences in the growth of the sugar beets were evident by thinning time. A growth sample taken April 30, 1952, indicated that the beets which followed vetch had made four times as much growth as those on the fallowed plots (Table 2). The growth following the barley and vetch mixture was about three times that following fallow, and the growth following barley was somewhat greater than that following fallow. These differences were correlated with the amount of nitrogen turned under in the green manures. Data from the analyses of petiole samples taken at thinning time showed that the growth differences were closely associated with the level of nitrate-nitrogen in the plants, further indicating that nitrogen nutrition was the primary limiting factor involved.

**Table 2.—Effect of Green Manure Crops on Sugar Beet Seedling Growth and Concentration of Nitrate-Nitrogen in Beet Petioles.**

| Treatment | Fresh Weight gm./top | Nitrate-N p.p.m. (dry basis) |
|---|---|---|
| Fallow | 7.1 | 980 |
| Barley | 12.0 | 2,060 |
| Barley and vetch | 20.9 | 4,790 |
| Vetch | 27.9 | 8,150 |
| L.S.D. 5% | 4.7 | 1,260 |

The growth differences demonstrated by the growth measurements at thinning time were maintained up to the harvest on the unfertilized plots. The harvest data show that the vetch green manure increased the root yield by 8.5 tons per acre with no appreciable drop in sucrose concentration (Table 3). The barley and vetch mixture increased root yield by 5.4 tons and the barley 1.7 tons. Fertilization of fallow plots with 120 pounds of

nitrogen per acre, approximately the same amount of nitrogen as was turned under in the vetch crop, increased the yield but did not increase it as much as the vetch green manure. This may be accounted for by the fact that the fallow plots were nitrogen-deficient prior to fertilization and never caught up in growth with the beets on the vetch plots (Table 4). The highest yields were obtained on the barley-vetch and vetch plots that received the additional nitrogen. The fertilizer nitrogen maintained the nitrate-nitrogen level in the plants above 1,000 p.p.m. for an additional month. However, the increased tonnage was accompanied by a 1.0 percentage point reduction in sucrose concentration. There was no significant difference between the fertilized barley-vetch and the fertilized vetch treatments, indicating that 120 pounds of fertilizer nitrogen plus 87 pounds of nitrogen in the barley-vetch green manure was adequate for maximum yields. However, fertilization produced a significant and profitable yield increase on all of the green manure treatments.

**Table 3.—Effect of Green Manure Crops and Nitrogen Fertilization on Sugar Beet Yield and Sucrose Concentration.**

| Treatment | Beet Yield (Tons/Acre) | | Sucrose Concentration (%) | |
|---|---|---|---|---|
| | No N | 120 N | No N | 120 N |
| Fallow | 13.5 | 19.3 | 16.9 | 16.2 |
| Barley | 15.2 | 23.2 | 16.7 | 16.3 |
| Barley and vetch | 18.9 | 27.1 | 16.6 | 15.6 |
| Vetch | 22.0 | 26.6 | 16.7 | 15.7 |
| L.S.D. 5%[1] | 1.7 | 2.2 | N.S. | 0.4 |

[1] Least significant differences at the 5 percent level for fertilizer levels for each green manure treatment ar 2.7 tons per acre and 1.0 percent sucrose.

In addition to the data on the nitrogen nutrition of the beets, Table 4 presents the results of petiole analyses for phosphate-phosphorus and potassium. Phosphorus was critically low only on the vetch plots and at the first sampling date. This was apparently a temporary nutrient imbalance in the plants brought about by the top growth outstripping the feeding power of the root system, since in subsequent samplings an adequate phosphorus level was regained. Potassium did not become a limiting factor in this experiment, and neither the phosphorus nor the potassium level in the plants was influenced in a major way by the green manure treatments.

To obtain information on the effect of the green manure treatments on soil structure, the rate of infiltration of water into the furrows between the beet beds was measured. This criterion was used because it is a characteristic which is very sensitive to the physical condition of the soil (1), and also because water penetration is a problem on many irrigated soils and of direct interest to the grower. No significant effect of the green manure treatments on water infiltration was observed. However, the average rate was 0.33 inches of water per hour, a very low rate for a soil of a sandy loam texture. Moreover, as the beets approached maturity they often wilted in large irregular spots throughout the field. Close examination of many of these spots showed a densely compacted zone between the 10- and 20-inch depths. Many of the beet tap roots were deformed by this condition (3). At harvest the numbers of deformed roots were counted

and found to be 9 percent of the total. There was no evidence that the number of deformed roots was reduced by any of the green manure treatments. Hence, on the basis of two types of observations it is evident that soil structure was not significantly influenced by the green manures.

Disease and insect pests were not a problem. There was a light infection of sugar beet mosaic, but its incidence was not associated with the treatments. The roots were free of disease over all treatments and no nematodes or serious insect infestations were observed in the experiment.

It is concluded from these observations and the data presented that the main effect of the green manure crops was on the nitrogen nutrition of the sugar beets and that this was closely related to the amount of nitrogen in the material turned under.

**Table 4.—The Effect of Green Manure Crops and Nitrogen Fertilization on the Nutritional Status of Sugar Beets as Indicated by Petiole Analysis (Dry Basis).**

| Treatment | Apr. 23 | May 30 | July 2 | Aug. 11 | Sept. 5 |
|---|---|---|---|---|---|
| | | | Nitrate-N (p.p.m.) | | |
| Fallow | 980 | 2,880 | 510 | 80 | 290 |
| Barley | 2,060 | 380 | 180 | 60 | 20 |
| Barley and vetch | 4,790 | 860 | 90 | 80 | 100 |
| Vetch | 8,150 | 2,560 | 450 | 70 | 80 |
| Fallow+ 120 N | 980 | 4,930 | 1,680 | 250 | 440 |
| Barley + 120 N | 2,060 | 4,420 | 520 | 120 | 110 |
| Barley and vetch + 120 N | 4,790 | 4,330 | 1,780 | 160 | 100 |
| Vetch + 120 N | 8,150 | 6,593 | 3,850 | 220 | 300 |
| | | | Phosphate-P (p.p.m.) | | |
| Fallow | 2,950 | 2,570 | 2,750 | 2,330 | 3,000 |
| Barley | 1,540 | 2,770 | 3,330 | 2,630 | 2,860 |
| Barley and vetch | 1,640 | 2,850 | 2,810 | 2,180 | 2,450 |
| Vetch | 490 | 2,650 | 2,420 | 1,900 | 2,100 |
| Fallow + 120 N | 2,950 | 2,320 | 1,480 | 1,720 | 2,000 |
| Barley + 120 N | 1,540 | 2,430 | 2,080 | 1,320 | 1,740 |
| Barley and vetch + 120 N | 1,640 | 2,350 | 1,790 | 1,680 | 1,880 |
| Vetch + 120 N | 490 | 2,380 | 1,530 | 2,140 | 1,950 |
| | | | Potassium (%) | | |
| Fallow | 3.6 | 3.2 | 2.9 | 4.0 | 5.0 |
| Barley | 4.5 | 3.7 | 3.7 | 4.5 | 4.6 |
| Barley and vetch | 4.0 | 3.1 | 3.5 | 4.1 | 4.3 |
| Vetch | 3.5 | 2.9 | 2.7 | 3.4 | 3.4 |
| Fallow + 120 N | 3.6 | 3.3 | 1.4 | 2.7 | 2.2 |
| Barley + 120 N | 4.5 | 3.0 | 1.8 | 2.0 | 2.4 |
| Barley and vetch + 120 N | 4.0 | 2.8 | 2.6 | 2.3 | 2.7 |
| Vetch | 3.5 | 2.9 | 1.8 | 2.8 | 2.3 |

**ACKNOWLEDGMENT**

The cooperation of Owen S. and Owen T. Rice in providing the land and performing the cultural operations for this experiment is gratefully acknowledged.

## Literature Cited

(1) DONEEN, L. D., and HENDERSON, D. W.
1952. Soil conditions affecting infiltration of water and root development of crop plants. Proc. Amer. Soc. Sugar Beet Tech. 214-223.

(2) PIETERS, A. J.
1927. Green manuring principles and practice. xiv +365 pp. Wiley, New York.

(3) RIETBERG, H.
1952. The influence of soil structure on the yield of sugar beets. Proc. Amer. Soc. Sugar Beet Tech. 150-152.

(4) ULRICH, A.
1948. Diagnostic techniques for soils and crops. Chap. VI. Plant analysis: methods and interpretation of results. 157-198. Amer. Potash Inst., Wash. 6, D. C.

(5) ULRICH, A., and HILLS, F. J.
1952. Petiole sampling of sugar beet fields in relation to their nitrogen, phosphorus, potassium and sodium status. Proc. Amer. Soc. Sugar Beet Tech. 32-45.

# Stand and Yield of Sugar Beets, and Weed Populations as Affected by: Broadcast Fertilization, Mechanical Thinning, Application of Herbicides and Their Interactions[1]

G. J. Hogaboam, H. W. Bockstahler, Buford H. Grigsby and George W. French[2]

Spring mechanization of sugar beet production has been the subject of considerable experimental work in recent years. Various recommendations concerning mechanical thinning and chemical weed control have been based on results from these experiments. A cooperative experiment was conducted to test combinations of some of the most promising recommendations. Three mechanical thinning treatments and both pre- and post-emergence applications of herbicidal sprays with suitable checks were tested on four rates of fertilization at East Lansing, Michigan.

## Experimental Design and Methods

The experiment was set up as a multiple-split plot randomized block design with eight replications of the main (fertilizer) plots. The main plots were twelve rows wide and 320 feet long. These main plots were split into three subplots (thinning) which were four rows wide and 320 feet long. The main plots were split in half lengthwise for post-emergence spray treatments (plots 12 rows wide and 160 feet long). These post-emergence spray plots were split in half again for pre-emergence spray treatments (plots 12 rows wide and 80 feet long).

A black root resistant variety of sugar beets, U. S. 400, was used. Processed seed, treated with a fungicide, was drilled at a depth of one inch in 28-inch rows at the rate of 5 pounds per acre. All plots received 200 pounds of 3-18-9 fertilizer per acre placed with the seed.

Experimental treatments in the order of splits in the design were as follows:

**Fertilizer**

$F_1$—0, $F_2$—500, $F_3$—1,000, and $F_4$—2,000 pounds per acre of 3-18-9 broadcast with a grain drill before seeding.

**Mechanical Thinning**

$T_1$—Spring-tined heads spacing cuts across the row 2½ inches apart for each of the two counter-rotating heads (this approximates two operations with a single head machine). Subsequently, these plots were blocked and thinned by hand labor.

---

[1] Cooperative investigations of the Field Crops Research Branch and the Agricultural Engineering Research Branch of the Agricultural Research Service, U. S. Department of Agriculture; and the Farm Crops, Botany and Plant Pathology, and Agricultural Engineering Sections of the Michigan Agricultural Experiment Station. Journal Article No. 1642, Michigan Agricultural Experiment Station.

[2] Research Agronomist, Plant Pathologist, and Plant Physiologist, Field Crops Research Branch, and Associate Agricultural Engineer, Farm Machinery Section, Agricultural Engineering Research Branch, respectively, Agricultural Research Service, U. S. Department of Agriculture.

$T_2$—Spring-tined counter-rotating heads with the spacing of the cuts across the row regulated at the discretion of the operator to compensate for variation in density of the beet stand. These plots were also blocked and thinned by hand labor.

$T_3$—Spring-tined counter-rotating heads with the spacing of the cuts across the row regulated at the discretion of the operator to compensate for variation in density of the beet stand. This treatment received no further blocking and thinning by hand labor.

All plots were hand hoed, to remove weeds after stand counts of beets and weeds had been made.

The thinner (1)[a] used in this experiment has two counter-rotating heads for each row and a variable speed drive. The rate of rotation can be changed quickly without interruption of the thinning and weeding action. This two-row machine is midmounted on the tractor and is driven by the power takeoff shaft. The depth-gauge wheels were adjusted to permit the spring tines to penetrate the soil to a depth of 1 inch for all of the thinnings. The tractor was operated in second gear at a speed of 2.8 miles per hour.

**Post-Emergence Herbicidal Spray**

$A_1$—a mixture of 5 pounds sodium trichloroacetate (TCA), 2 pounds of endothal and 30 gallons of water per acre.

$A_2$—No post-emergence herbicidal spray.

The sprayer was mounted on the tractor immediately behind the thinner heads with separate controls for the thinner and sprayer such that either operation could be used independently or both used simultaneously.

**Pre-Emergence Herbicidal Spray**

$P_1$—5 pounds TCA, 2 pounds sodium pentachlorophenate (PCP) and 40 gallons of water per acre.

$P_2$—No pre-emergence herbicidal spray.

All herbicidal sprays were applied in a 6-inch band centered over the row.

In order to determine the effectiveness of the pre-emergence spray and to establish a basis for evaluating the methods of thinning and effects of post-emergence sprays, stand counts of grasses, broad-leaved weeds, and beets were made. Permanent sites were established in each plot and all plant counts were made at these locations. Beet counts were made in 100-inch row lengths in both center rows of each plot. Within this area of a plot, weed counts were made on 6 sites, 4 inches by 12 inches, centered lengthwise on the row. A second count was made after mechanical thinning and post-emergence spraying had been completed. After the second counts had been made, the plots were given cultivation and hand hoeing as required to control weeds. The beets in each plot were counted again just before harvest. At harvest, root yields, number of marketable beets, sucrose percentage, and purity were determined for each plot.

---

[a] Numbers in parentheses refer to literature cited.

### Summary of Variables

$F_1$—No fertilizer.
$F_2$—500 pound per acre 3-18-9 broadcast.
$F_3$—1,000 pounds per acre 3-18-9 broadcast.
$F_4$—2,000 pounds per acre 3-18-9 broadcast.
$T_1$—Fixed speed mechanical thinning, hand blocking and thinning.
$T_2$—Variable speed mechanical thinning, hand blocking and thinning.
$T_3$—Variable speed mechanical thinning, no hand blocking or hand thinning.
$A_1$—Post-emergence spray.
$A_2$—No post-emergence spray.
$P_1$—Pre-emergence spray.
$P_2$—No pre-emergence spray.

### Schedule of Operations

| OPERATIONS | DATE |
|---|---|
| Planting | May 25 |
| Pre-emergence spray | May 29 |
| First count (beets, grasses, broad-leaved weeds) | June 11-12 |
| Mechanical thinning, Post-emergence spray | June 12-13 |
| Second count (beets, grasses, broad-leaved weeds) | June 24-25 |
| Hand hoeing all plots (weeds only) | July 7-9 |
| Hand blocking and thinning stand of beets ($T_1$ and $T_2$ only) | July 16-17 |
| Pre-harvest count of beets | Sept. 28 to Oct. 3 |
| Harvesting | Oct. 5 to 15 |

### Discussion of Results

**A. Broadcast Fertilizer.**

Although there was a significant increase in yield from fertilizer (Table 1), the broadcast method of fertilization did not give a profitable return under the conditions of this experiment. It should be pointed out, however, that the broadcast fertilization gave varying nutrient levels with which to assess the relative importance of beet-weed competition for nutrients. This will be discussed later under interactions.

**B. Thinning Treatments**

Statistically significant differences between treatments were obtained for: stand before harvest, number of marketable beets, percentage of marketable beets, tons of roots, and gross and net sucrose[4] (Table 1). The lower yield of $T_3$ plots probably was a result of uneven distribution of the beets, which led to severe competition where they were bunched together, rather than a result of greater numbers of beets. The differences between thinnings, shown at harvest, can be ascribed to hand blocking and thinning since stand differences between the three treatments at the time of the second count were not significant. Proportionately greater removal of broad-leaved weeds, as compared to grasses, was effected by mechanical thinning. This can be observed in the "no spray" treatment of Table 2.

[4] Gross sucrose x percentage purity.

**Table 1.—Numbers of Sugar Beet Roots, Yields, and Percentages of Sucrose and Purity as Affected by Fertilization, Thinning, and Herbicidal Sprays.**

| | Fertilizers | | | | L.S.D. | | Thinnings | | | L.S.D. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $F_1$ | $F_2$ | $F_3$ | $F_4$ | 5% | 1% | $T_1$ | $T_2$ | $T_3$ | 5% | 1% |
| Stand before Harvest (per 100′) | 76.5 | 75.6 | 88.1 | 87.5 | N.S. | N.S. | 81.3 | 73.1 | 93.3 | 6.2 | 8.3 |
| Number Marketable Beets (per 100′) | 61.5 | 62.4 | 73.9 | 70.9 | 8.8 | N.S. | 66.5 | 62.8 | 72.2 | 3.4 | 4.6 |
| Percent Marketable Beets | 84.3 | 84.9 | 84.3 | 84.6 | N.S. | N.S. | 85.0 | 87.7 | 80.9 | 1.9 | 2.5 |
| Tons of Roots per Acre | 8.50 | 9.04 | 10.01 | 10.20 | .68 | .92 | 9.69 | 9.67 | 8.95 | .37 | .49 |
| Gross Sucrose (pounds per acre) | 2,682 | 2,820 | 3,194 | 3,181 | 235 | 318 | 3,052 | 3,034 | 2,821 | 114 | 152 |
| Net Sucrose (pounds per acre) | 2,118 | 2,237 | 2,541 | 2,482 | 195 | 264 | 2,411 | 2,392 | 2,231 | 88 | 117 |
| Percent Sucrose | 15.77 | 15.54 | 16.02 | 15.57 | N.S. | N.S. | 15.72 | 15.70 | 15.76 | N.S. | N.S. |
| Percent Purity | 78.84 | 79.13 | 79.38 | 77.82 | N.S. | N.S. | 78.82 | 78.65 | 78.92 | N.S. | N.S. |

| | Herbicidal Sprays | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Pre-emergence | | L.S.D. | | Post-emergence | | L.S.D. | |
| | $P_1$ | $P_2$ | 5% | 1% | $A_1$ | $A_2$ | 5% | 1% |
| Stand before Harvest (per 100′) | 80.3 | 85.0 | 3.3 | 4.4 | 73.4 | 91.8 | 4.7 | 6.4 |
| Number Marketable Beets (per 100′) | 65.8 | 68.5 | 2.6 | N.S. | 60.4 | 73.9 | 3.2 | 4.3 |
| Percent Marketable Beets | 85.7 | 83.3 | 1.2 | 1.6 | 85.3 | 83.7 | 1.8 | 2.4 |
| Tons of Roots per Acre | 9.68 | 9.19 | .28 | .37 | 8.87 | 10.00 | .56 | .77 |
| Gross Sucrose (pounds per acre) | 3,029 | 2,909 | 102 | N.S. | 2,749 | 3,190 | 175 | 236 |
| Net Sucrose (pounds per acre) | 2,386 | 2,303 | N.S. | N.S. | 2,157 | 2,533 | 136 | 197 |
| Percent Sucrose | 15.62 | 15.84 | .15 | .19 | 15.51 | 15.95 | .26 | .35 |
| Percent Purity | 78.52 | 79.07 | .44 | N.S. | 78.27 | 79.32 | .67 | .90 |

**Table 2.—The Effects of Herbicidal Sprays on Weed and Sugar Beet Stand, Yield, and Sugar Production.**

| | Weeds Per 100 feet of 4-inch strip centered on row. | | | | | | Beets | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grasses | | Broad-leaved | | Total | | Beets Per 100′ of Row | | Tons Acre Beets | Percent Sucrose | Percent Purity | Net Sugar |
| | [1]1st | 2nd | [1]1st | 2nd | [1]1st | 2nd | [1]1st | 2nd | | | | |
| Pre-plus Post-emergence | 35.3 | 4.0 | 866.6 | 135.2 | 902.9 | 139.2 | 370.8 | 113.6 | 8.9 | 15.43 | 77.94 | 2,144 |
| Pre-emergence | 49.3 | 22.0 | 834.5 | 168.7 | 883.8 | 190.7 | 380.9 | 144.2 | 10.5 | 15.82 | 79.14 | 2,629 |
| Post-emergence | 601.5 | 230.7 | 2,049.0 | 315.1 | 2,650.5 | 545.8 | 447.3 | 149.7 | 8.8 | 15.59 | 78.64 | 2,170 |
| No spray | 515.1 | 237.5 | 1,928.0 | 447.7 | 2,443.1 | 685.2 | 450.2 | 185.8 | 9.5 | 16.09 | 79.55 | 2,437 |

[1] At the first count only the pre-emergence spray had been applied. Data for pre- plus post- and post-emergence spray are included to give a basis for evaluating the second count since the initial stands could not be assumed to be uniform. It should be noted also that mechanical thinning between the first and second counts reduced weed and beet counts of all treatments.

Thinning treatments $T_1$ and $T_2$ required 22.8 additional man hours per acre for blocking and thinning. Thus, $T_1$ and $T_2$ cost $15.90 more per acre than $T_3$ which received only mechanical thinning. This additional cost was not offset by the income from the significantly higher yields (Table 1) of $T_1$ and $T_2$ over $T_3$. As mentioned previously, thinning method $T_3$ was performed with a variable speed thinner; therefore, operator skill influenced these results.

**C. Herbicidal Application**

In Table 2, the data have been arranged to show the effects of pre-emergence, post-emergence, and a combination of the two treatments in comparison with no herbicidal spray. These pooled values include all rates of fertilization and all thinning methods.

The combination of TCA and PCP, as a pre-emergence spray, gave excellent control of grasses at the time of beet emergence and this herbicidal treatment continued to retard the emergence of weeds for approximately one month. The control of broad-leaved weeds was not equal to that of grasses but measurable effects were obtained. Sufficient weed control was obtained from the pre-emergence treatment to significantly increase root yields. This effect on root yields was initiated early in the growing season, since weeds were removed by hand labor 6 weeks after planting. This is one of the most important results of the experiment.

Post-emergence spraying generally gave good control of broad-leaved weeds and lesser effects on grasses present at the time of spraying. Field observations, however, indicated that late grass emergence was reduced in the sprayed plots. This effect probably was due to some residual effect of the TCA. Some burning was observed on the beet leaves but this injury did not visibly affect the subsequent top growth of the beet seedlings.

The combination of pre- and post-emergence sprays brought about the greatest reduction in stand of weeds and of beets. Enough beets were left, however, to produce an acceptable commercial stand. Yields of beets were reduced significantly as a result of post-emergence spraying. Pre-emergence spraying alone gave a significant increase in acre yield of roots and in percentage of marketable beets.

Herbicidal treatments caused a significant, 1 percent level, reduction in sucrose percentages and purity coefficients. Post-emergence spraying reduced the net sugar production whereas pre-emergence spraying did not.

Data obtained at harvest indicate that post-emergence sprays may have produced some fundamental effects upon the physiological activity of the beets. This is reflected in the lower yield of beets, percentage sucrose and purity, and net sugar. Immediately after the spray application some leaf injury was observed but as the season advanced the sprayed beets were not visibly different from the unsprayed beets.

Unpublished data [8] have shown that endothal also may have marked effects upon some cell processes, especially on mitotic division. Thus, dis-

[8] Personal communication from G. B. Wilson, cytologist, Department of Botany and Plant Pathology, Michigan State College.

turbances in the manufacture or movement of materials within the plants may have occurred. The data do not permit a determination of the direct cause. Further studies of the effects of herbicides upon the growth of sugar beets are needed before general use of post-emergence sprays is recommended.

The effects of combined pre- and post-emergence sprays appear to be merely additive, and with no marked interaction. It is possible that in this experiment there was some carry-over effect on grass emergence but no other important effects were observed.

While time-lapse studies were not made, the reductions in weed population, following pre-emergence treatment, were large enough to suggest that substantial savings in time required for weed removal were effected.

**D. Interactions**

The main factors which interacted to influence the yield are given below:

**1. Early plant competition.**

Early competition among all plants, beets and weeds could be measured by comparing the yields of those plots receiving only a

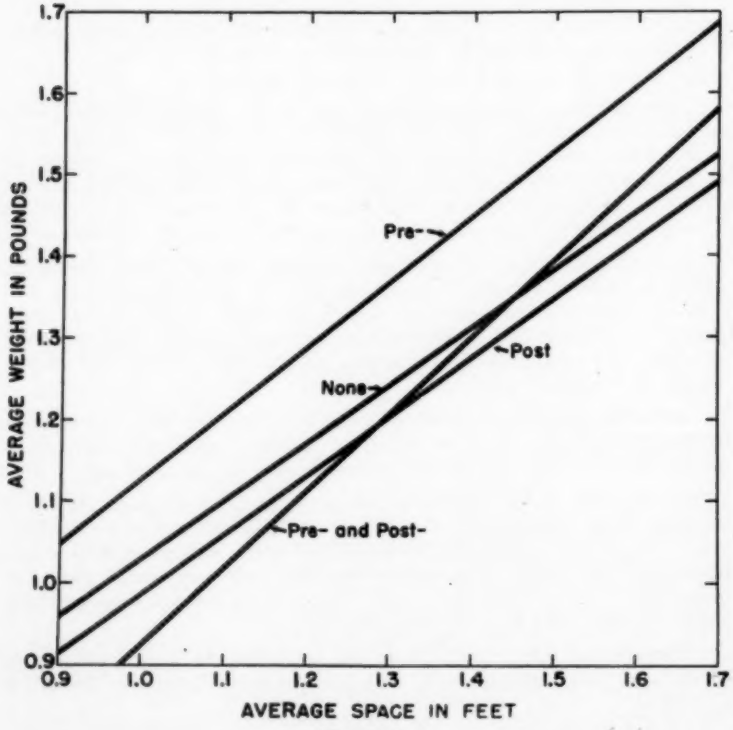


**Figure 1.**

pre-emergence spray with those receiving no herbicidal spray. Competition in the first few weeks after planting gave a negative correlation (—.48, significant at the 2 percent level) with the final yield. As might be expected, the correlation was highest with no broadcast fertilization (—.975, significant at the 1 percent level). Those plots receiving post-emergence spray were omitted from the above calculations due to the detrimental effect of the spray.

**2. Effect of the post-emergence spray.**

In Figure 1, the slopes of the lines were not significantly different from each other. While the pre-emergence (pre-emergence only) treated beets were larger for any given spacing, subsequent application of a post-emergence treatment (pre- plus post-emergence) counteracted the advantage of the preemergence treatment. This apparent decrease in weight-space response appears as indicative of at least a temporary upset in the metabolism of the beets. It should also be noted (Figure 3) that in general the number of beets at harvest was lower whenever a post-emergence treatment was applied. These two effects are evident in the yield data (Figure 4) at the higher rates of fertilization. Where there was no broadcast fertilization, early plant competition played a dominant role in determining the final yield, thus masking the effect of the post-emergence treatment.

**3. Competition among the beets.**

The competition of beets among themselves after thinning affected yield. This is especially evident in the $T_3$ plots where local crowding of beets was judged to be primarily responsible for the decreased yield.

With the above interactions in mind it is possible to evaluate the yield data (Figure 4) on the basis of the integrated effect of early competition (Figure 2), beet stands at harvest (Figure 3), the weight-space ratio (Figure 1), and the local crowding observed in the $T_3$ plots.

The consistently greater yield of plots receiving only pre-emergence spray may be attributed most logically to the reduced early competition from weeds. The unsprayed treatment was consistently next highest in yield. The early competition from weeds apparently reduced this yield as compared to plots receiving only pre-emergence spray. The plots receiving a post-emergence spray yielded the least.

In general, the effect of the post-emergence spray treatment was so pronounced that the potential advantage of the pre-emergence spray in reducing early competition as compared to no pre-emergence spray was obscured. The lower yield of the post-emergence spray plots apparently resulted from an adverse effect on weight as shown by the weight-space ratio and also from a slight reduction in number of beets.

In the plots receiving no broadcast fertilization, the above trends were largely obscured by the severe competition for nutrients, especially during the early stages of plant growth. In contrast, early competition appears to be less of a factor where more nutrients are available since the yield of the unsprayed plots tended to approach the yield of the pre-emergence sprayed plots at the highest rate of fertilization.

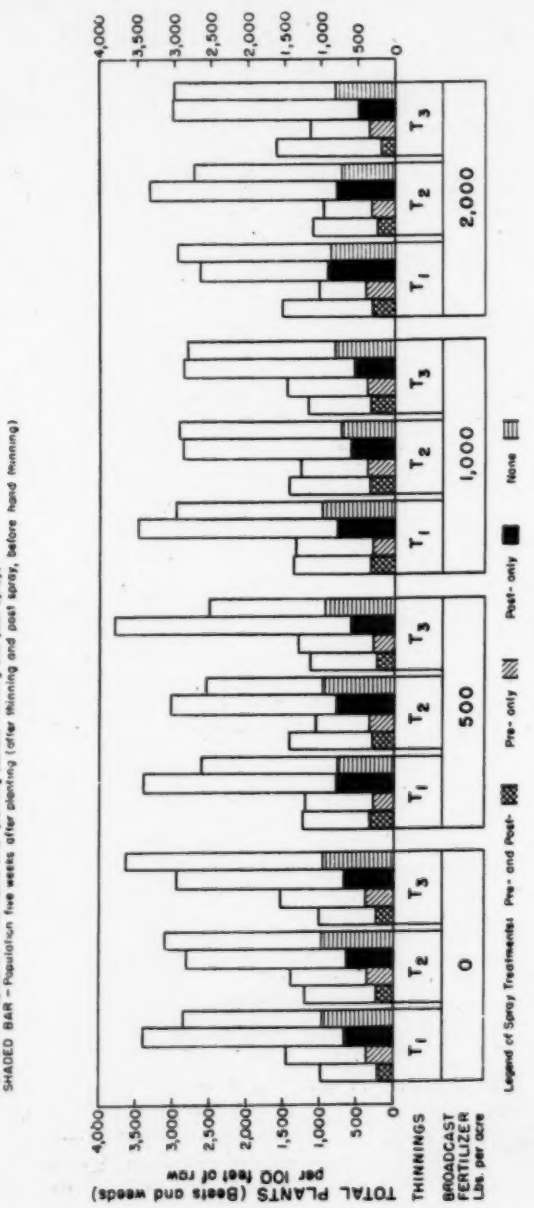
TOP BAR – Population three weeks after planting (before thinning and post spray)
SHADED BAR – Population five weeks after planting (after thinning and post spray, before hand thinning)
TOTAL PLANTS (Beets and weeds) per 100 feet of row
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
THINNINGS
BROADCAST FERTILIZER Lbs. per acre
T1 T2 T3
0
500
1,000
2,000
Legend of Spray Treatments: Pre- and Post-
Pre- only
Post- only
None

Figure 2.

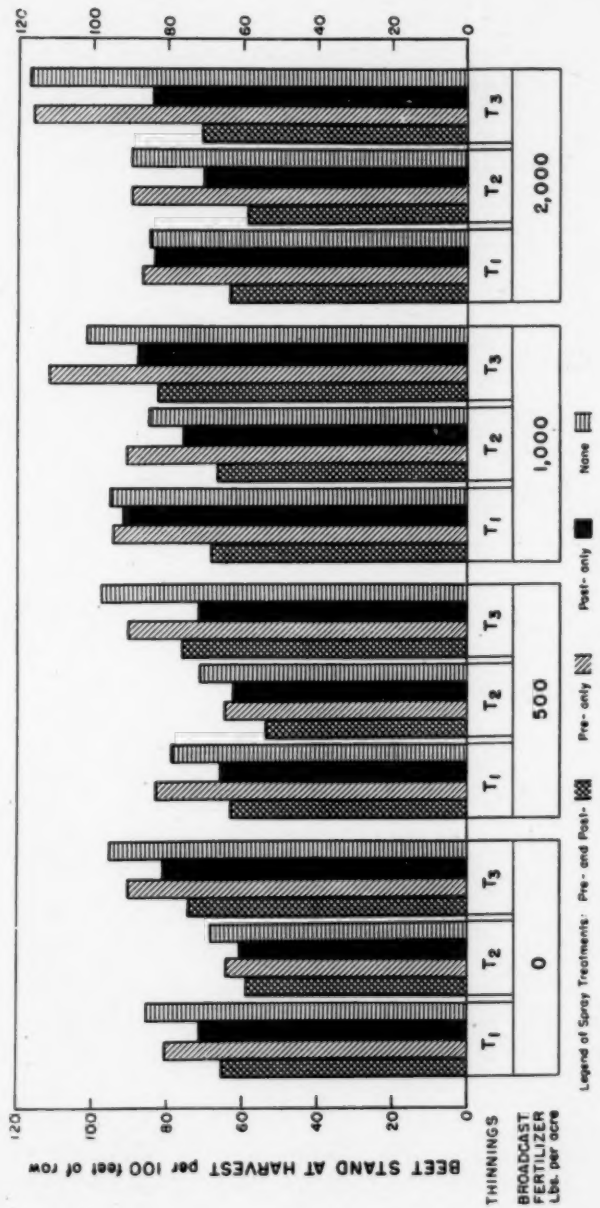
BEET STAND AT HARVEST per 100 feet of row
120
100
80
60
40
20
0
THINNINGS
BROADCAST FERTILIZER Lbs. per acre
T1
T2
T3
0
500
1,000
2,000
Legend of Spray Treatments: Pre- and Post-
Pre- only
Post- only
None

Figure 3.

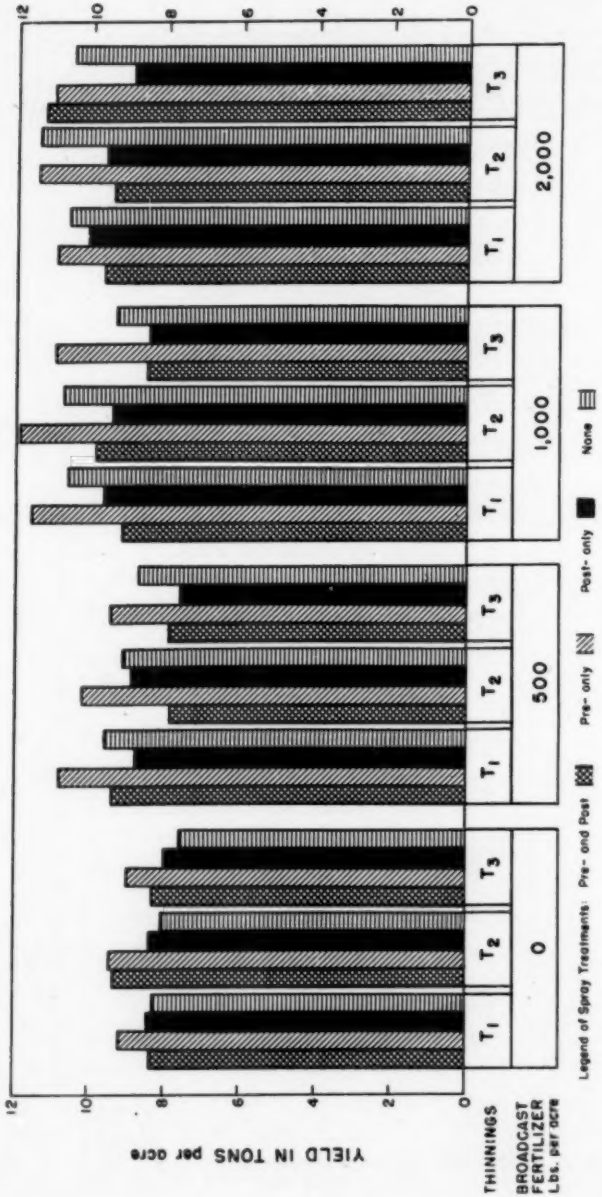
YIELD IN TONS per acre
0
2
4
6
8
10
12
THINNINGS
BROADCAST FERTILIZER Lbs. per acre
0
500
1,000
2,000
T1
T2
T3
Legend of Spray Treatments: Pre- and Post
Pre- only
Post- only
None

Figure 4.

**Summary**

1. Broadcast fertilization at the rates of 1,000 and 2,000 pounds per acre significantly increased the yield over rates of 0 and 500 pounds per acre.

2. Broadcast fertilization was not an economical method of applying fertilizer.

3. The mechanically thinned plots receiving additional hand labor for blocking and thinning yielded significantly more than those plots thinned entirely by machine. However, under the conditions of this experiment, the increase in yield was insufficient to pay for the cost of the additional labor.

4. All three mechanical thinning treatments were more effective in reducing the populations of broad-leaved weeds than that of grasses.

5. Pre-emergence applications of a mixture of TCA-PCP gave effective control of grasses and a less satisfactory control of other weeds.

6. Beet stands were reduced by pre-emergence sprays but stands were adequate to produce a good yield of beets.

7. Yields were significantly increased by pre-emergence spraying.

8. Pre-emergence application of a mixture of TCA and PCP gave effective control of weeds in sugar beets and this mixture of herbicides is suggested for grower use.

9. Post-emergence spraying with a mixture of TCA and endothal gave control of broad-leaved weeds but was not satisfactory for grasses.

10. Post-emergence spraying reduced the yield of beets and affected adversely sucrose and purity percentage with a resultant decrease in net sugar.

11. The post-emergence herbicide may have upset the metabolism of the beets, since, for any given spacing, the postemergence sprayed beets weighed less than the unsprayed beets.

12. Post-emergence applications of a mixture of TCA and endothal is not recommended.

13. Early plant competition among beets and weeds gave a significant negative correlation with yield. This correlation was most pronounced at the lower fertility levels.

14. The local, severe crowding of beets, particularly evident in the all-mechanically thinned plots, apparently affected yield adversely.

**ACKNOWLEDGMENTS**

Acknowledgment is made to Dr. F. W. Snyder, plant physiologist, Field Crops Research Branch, U. S. Dept. of Agriculture, for valuable assistance. Acknowledgment is also made to George R. Stafford, engineering aid, Farm Machinery Section, U. S. Dept. of Agriculture, for his help.

**Literature Cited**

(1) FRENCH, GEORGE W.
1952. A report on tests of mechanical weeding and thinning equipment in Michigan. Proc. Am. Soc. Sugar Beet Tech. PP. 586-590.

# Irrigation and Fertility Studies on Sugar Beets at Logan, Utah[1]

VAUGHN E. HANSEN[2] AND JAY L. HADDOCK[3]

## Introduction

The combination of irrigation treatment and fertilizer application which will produce maximum sugar beet yields and quality is a major concern to growers as well as to processors of sugar beets. This paper is a discussion of factors which affect yield and quality of beets in the light of results obtained during 1952 from a crop rotation experiment being conducted at the Greenville Farm at Logan, Utah. The data presented herein will indicate how the yield, sugar percentage, and purity percentage are related to the soil fertility conditions and irrigation treatments.

Four fertilizer treatments were involved as follows: O=no fertilizer; P=100 pounds of $P_2O_5$; N=80 pounds of nitrogen; NP=100 pounds of $P_2O_5$ and 80 pounds of nitrogen.

The irrigation consisted of two methods—furrow and sprinkler, described as "F" and "S" respectively; each having four moisture levels. The driest level designated as 1 was too dry for optimum production, and the wettest designated as 4 was maintained in a very moist soil condition. The other levels were spaced between these two extremes which were designed to bracket the optimum growing conditions.

The problem of management of the irrigation water made it impractical to maintain exactly the same moisture conditions in furrow as in the sprinkler plots. Hence, the data presented relative to the amount of irrigation water used will be in terms of the actual amount of water applied including rainfall plus any net moisture removed from the soil during the growing season. These data on total water used by the sugar beet crop are plotted on the abscissa of the figure.

## Results

The relationships between fertilizer and irrigation treatment as measured by yield are shown in Figure 1, as measured by sugar percentage in Figure 2, and as measured by purity percentage in Figure 3.

Block diagrams have been chosen for this presentation because of the ability to show important trends and general relationships which often times are not evident from other methods of analysis.

The abscissa to the left shows the fertility condition whereas the abscissa to the right portrays water management. The vertical ordinates in the three figures represent yield, sugar percentage, and purity percentage, respectively.

---

[1] The data in this paper were obtained at the Utah Agricultural Experiment Station under Project W-9 with the 11 western states, Hawaii, and the Soil and Water Conservation Branch of the Agricultural Research Services, USDA, cooperating.

[2] Irrigation engineer, Soil and Water Conservation Branch, Agricultural Research Services, USDA; research associate professor of irrigation and drainage, Utah State Agricultural College, Logan, Utah.

[3] Soil scientist, Soil and Water Conservation Branch, Agricultural Research Service, USDA, Logan, Utah.

**Yield**

The most noticeable trend in yield is the decided increase with increased water. A plateau is reached in the yield with about 18 irrigations at 1.1 inches per irrigation or a total water application, including rainfall and soil moisture depletion, of 25 inches of water, after which little benefit is received from added increments.

It is interesting to note that, in every case, the furrow plots, shown by the solid lines, received more water than the supposedly comparable sprinkler plots, shown by dotted lines. Analyzing yield in terms of moisture regime alone would lead one to the generality that furrow irrigation gave better yield than sprinkler irrigation. Observations in previous years lead to contrary conclusions. Sprinkler irrigation has been shown to be especially advantageous on the wetter plots. However, Figure 1 shows that, when considered in terms of actual water applied, both methods were comparable. The difference in yield observed between the two methods was owing to the frequency of irrigation and to the amount of water applied.

Fertility treatments produced an interesting effect on yield. Under dry conditions the yield response was principally to phosphorus. Phosphorus appeared to affect yields favorably at all soil moisture conditions while nitrogen appeared to have a favorable influence only under high soil moisture conditions. In previous years, phosphorus has shown little influence on yield, whereas nitrogen has given significant yield increases.

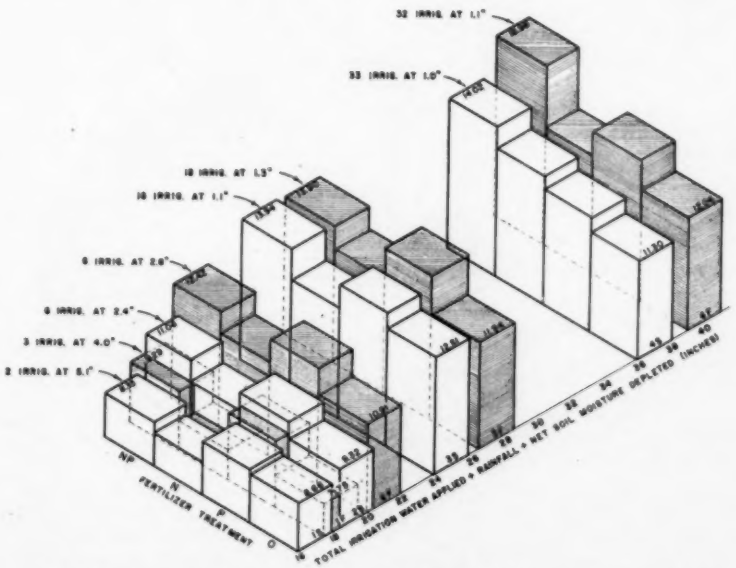


**Figure 1.—Yield of sugar beets as influenced by fertilization and irrigation treatment (1952).**

The minimum yield was obtained under the driest treatment with the maximum yield coming from ample water and ample fertilizer. The general trend from a minimum fertility and minimum water to a maximum yield with maximum fertility and maximum water is evident. The general trend and overall relationship as illustrated in the three-dimensional block diagram are informative.

**Sugar Percentage**

The most noticeable increase in sugar percentage portrayed in Figure 2 is with increased water. A plateau similar to the one in Figure 1 is reached after about 18 irrigations at 1.1 inches per hour, or total water use of 25 inches. Additional irrigations result in little if any increase in the sugar percentage. Previous studies have shown a consistent tendency for sucrose to increase with increasing amounts of irrigation water.

There appears to be a slightly beneficial effect in sucrose percentage for phosphorus fertilization while nitrogen has a depressing effect. It appears that phosphorus is slightly beneficial toward increasing sugar percentage after the plateau is reached.

A comparison of sprinkling and furrow irrigation from the viewpoint of sugar percentage as shown in Figure 2 leads to the same conclusions as were obtained from Figure 1, *i.e.*, the difference in the two methods of irrigation appears to be largely a difference in the amount of water applied. This is contrary to previous observations. Sprinkler irrigation has generally resulted in a slightly lower sucrose percentage even when similar quantities of water were used.

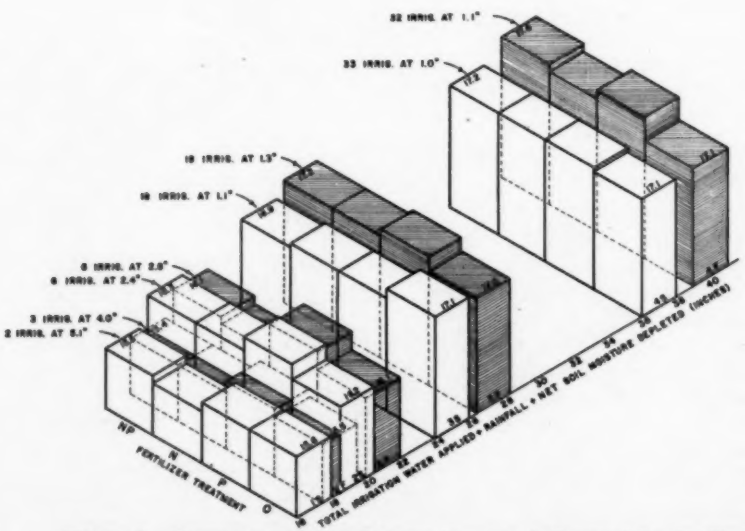


**Figure 2.—Sugar percentage of sugar beets as influenced by fertilization and irrigation treatment (1952).**

**Percent Purity**

The data in Figure 3 relating the percent purity of sugar beets to fertilizer and irrigation practice produces a picture comparable to that obtained in Figures 1 and 2. Twenty-five inches applied in 18 irrigations led to essentially a plateau where additional irrigation produced only slight increases in percent purity. It may be observed that phosphorus tended to influence percent purity favorably, while nitrogen depressed it at low moisture levels and had no effect at high soil moisture levels. Phosphorus fertilizer alone tended to result in higher purities than when combined with nitrogen.

In 1952 the amount of irrigation water used was closely correlated with yield and quality.

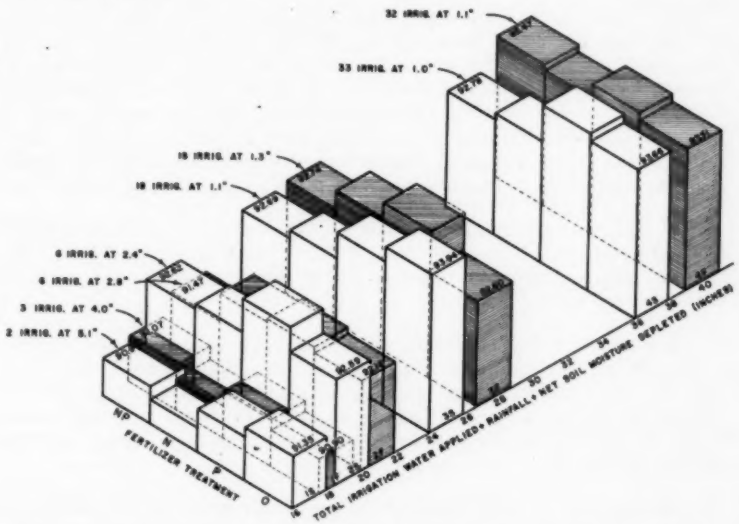


**Figure 3.—Purity percentage as influenced by fertilization and irrigation treatment (1952).**

## Discussion and Summary

The yield and quality data obtained in 1952 are not typical of those for the area. What explanation suitably explains the results presented?

The normal sugar beet season from planting to harvest in Utah is from 180 to 190 days. In 1952 there was practically no spring weather. An abrupt break from winter to summer occurred the last of April. The soil surface dried unfavorable to planting and delayed this operation nearly three weeks. Thinning was two to three weeks later than usual and the plants were actually about one month behind plants grown in more normal seasons at the same date. In addition, the harvesting season was about ten days ahead of the previous seasons.

The short season of approximately 160 days may account for low yields but how about the unusual response to fertilizers?

It has previously been proposed (1)[4] that the soil must provide 10 pounds of nitrogen for each ton of beets produced. It has also been suggested that typical soils in the Great Basin are able to supply from 100 to 160 pounds of nitrogen per acre. During short seasons when limitation of climate makes it possible to produce only 15 to 16 tons of beets, the soil is able to supply ample nitrogen for the crop. Under these conditions additional nitrogen fertilizer apparently does not contribute toward increased yields but may have an adverse affect on yield as well as on sucrose and purity percentages. Under conditions of high nitrogen supply, phosphorus fertilizer benefits yield and is favorable to high sucrose and purity.

This explanation appears to be borne out by the chemical composition of sugar beet petioles at harvest time. Whereas the petioles from the dry plots (1S, 1F, 2S, and 2F) averaged about 1,500 p.p.m. nitrate-nitrogen at harvest time in 1950, petioles from the dry plots in 1952 averaged about 3,000 p.p.m. at harvest time. The phosphorus content of beet petioles in 1952 was only half the concentration observed in petioles in 1950. It is believed that these facts may partially help to explain the yield and quality response of sugar beets to irrigation and fertilizer treatments in 1952.

In 1952, nitrogen produced slight if any benefit. Certainly the benefit received would not justify the cost. On the other hand, phosphorus fertilization had a stimulating influence on all three quantities, but was most noticeable on yield.

A word of caution should be given with regard to the irrigation practice under wet soil conditions. In all cases, light applications of water were applied. Frequent irrigations should consist of light applications since the soil will only hold a limited amount of water. Excessive downward movement of water beyond the root zone resulting in leaching of plant nutrients should be reduced to a minimum.

The three figures illustrate that for sugar beet production the difference between surface and sprinkler irrigation may be, in part at least, a difference in water control and management. The furrows are close enough and the roots deep enough during the latter portion of the season that both methods do a reasonably good job of storing water in the soil if there is good control. Local factors such as topography, water supply and depth of soil will determine which method is best suited to sugar beet culture on a particular farm; the choice being determined by which method will enable the best control of the water. Such factors as the need for germination and early irrigation, and the ability to apply light applications of water early in the season, will influence the choice of the method of irrigation, but a discussion of these factors is beyond the scope of this paper.

In previous years phosphorus fertilization has shown little if any benefit and nitrogen fertilizer has stimulated yield. The combination of both

[4] Numbers in parentheses refer to literature cited.

phosphorus and nitrogen has always given greater yields than either alone. This type of response depends upon the soil fertility conditions as well as climatic conditions under which the crop is grown.

It has also been observed in previous years that 80 pounds of nitrogen has increased yields, and also depressed sucrose percentage and purity of beets. This phenomenon was not manifest in 1952. An explanation for this lack of uniformity is the short season in 1952 and the fact that the low yield of beets did not place the heavy demand upon nitrogen fertilizer exhibited in previous years.

### Literature Cited

(1) HADDOCK, JAY L.
1952. The nitrogen requirement of sugar beets. Proc. Amer. Soc. Sugar Beet Tech. pp. 159-165.

# Sugar Beet Irrigation Experiments in Wyoming[1]

W. McNab Miller, Jay R. Partridge and Carrol Tyler[2]

Experimental material reported in this paper was developed during three years of irrigation experiments by the University of Wyoming Agricultural Experiment Station in cooperation with the Great Western Sugar Company and Holly Sugar Corporation at a number of locations throughout Wyoming:[3]

| | |
|---|---|
| Big Horn Basin: | 1951 Powell, Cowley, Worland |
| | 1952 Powell, Worland (new location) |
| | 1953 Powell (new location) |
| Southeastern Wyoming: | 1951 Wheatland, Torrington |
| | 1952 Wheatland, Torrington |
| | 1953 Torrington (new location) |

This paper discusses only the principal objective of determining how dry the soil might be permitted to become before a significant reduction occurred in yield or sugar. Supplementary observations and analysis, of much value in interpreting results and in improving methodology, are not reported.

## Procedure

Experimental design consisted of a single applied variable of the availability of soil moisture in the field immediately before irrigation. Fertility was minimized as a factor by selecting fields with a history of generally high yields and operated by growers of known ability, and by applying fertilizers each year according to the best available recommendations. The soil moisture availability was expressed in atmospheres tension as being the least affected by differences in soil texture, fertility, compaction and climate of the currently used methods of expressing soil moisture. While not directly usable by the grower, establishment of critical levels of moisture tension for irrigation appears to offer basic recommendations most stable over a wide range of soil types and climatological regimes.

Bouyoucos block electrical soil moisture units were used to determine soil moisture tensions throughout this study. As used in outfield work, all resistance readings were corrected for temperature and converted to atmospheres tension by means of a family of tension-resistance laboratory curves. Adjustments were made for calibration drift in the field.

Each experiment consisted of 16 plots comprising 4 replications of 4 irrigation treatments. Plots, 8-12 rows wide, were considered to be 100 feet long, although at some locations it was necessary to irrigate 300 feet

---

[1] Published with approval of the Director, Wyoming Agricultural Experiment Station, as Journal Paper No. 47.

[2] Assistant agricultural engineer, University of Wyoming, Laramie, Wyoming; soils technicians at the Powell and Torrington experimental substations, respectively.

[3] The authors are indebted to the Great Western Sugar Company and the Holly Sugar Corporation and to their personnel for physical assistance and many helpful suggestions, and to a number of commercial sugar beet growers for the use of part of their land and for their cooperative interest in the investigations.

of row to fit with irrigation practices over the balance of the field. The plots at Torrington in 1953 were situated on the experimental substation. All other experimental sites were located on fields of commercial growers after the planting and emergence of the sugar beets. Nominal irrigation treatments were to apply irrigation water in some excess to assure root zone saturation, when the soil-moisture tension reached 1 atmosphere (W-4), 2 atmospheres (W-3), 4 atmospheres (W-2), and 8 atmospheres (W-1). Yield determinations were made from 100 feet of the two central rows of each plot, hand topped, and washed at the nearest sugar factory.

## Results

### 1951

New soil moisture units installed at all locations were found to be faulty and were replaced at midseason. The consequent root zone disturbance was found to render much of the moisture-tension data unreliable. While of invaluable assistance in refining subsequent field work and in indicating yield trends, results are not considered sufficiently precise to warrant reporting in this paper.

### 1952

Two columns of Bouyoucos blocks were installed in each plot at the upper and lower ¼ length of one of the harvest rows (50 feet between columns) at depths of 6 inches, 18 inches, 30 inches, and 42 inches. Irrigations were based on the mean of four replicates. These means were calculated for the 6 inch units at the start of the season, on the average of the 6 inch and 18 inch units when the latter showed a tension rise above field capacity (presumed to indicate progressive root development), and on a mean of the 18 inch and 30 inch units when the latter showed a tension increase.

Tensions on which irrigations were scheduled, were therefore a mean of 8 block readings when a single horizon was used, and a mean of 16 block readings when two horizons were averaged. At the end of the season blocks were excavated, and all readings prior to irrigations were adjusted for the indicated calibration drift.

The assumption that root penetration would be indicated by tension rises and that therefore mean tensions would indicate the lower ⅔ of the root zone was found to be untrue. This fact, plus indications that yields may be more closely correlated with the tension at 6 inches than at 18 inches (or the mean of the 6 inch and 18 inch tensions), directed the reporting of all tensions as a mean for single horizons. Departures from intended treatment tensions which may be observed in Table 1 are the combined result of the change in the method of calculating means and the postseason calibration corrections. Mean integrated tensions were calculated for all plots by a method similar to that described by Taylor (1)[4]. The data are not reported since no advantage was found for expressing mean tensions in this manner, and in comparing Wheatland and Torrington data, this appeared to mask causative data. Seasonal mean peak tensions in atmospheres are presented in Table 1.

[4] Numbers in parentheses refer to literature cited.

Table 1.—Mean Atmosphere Peak Tension, 1952.

| Location | | Treatment | | | |
|---|---|---|---|---|---|
| | | W-1 (8 atm) | W-2 (4 atm) | W-3 (2 atm) | W-4 (1 atm) |
| Powell | Mean 6" depth | 8.0 | 6.0 | 4.3 | 2.9 |
| | Mean 18" depth | 6.7 | 5.5 | 2.0 | 1.3 |
| | Number of peak tensions | 2 | 3 | 4 | 6 |
| Worland | Mean 6" depth | 10.2 | 4.1 | 3.0 | 2.2 |
| | Mean 18" depth | 3.3 | 0.6 | 0.3 | 0.4 |
| | Number of peak tensions | 2 | 4 | 5 | 6 |
| Wheatland | Mean 6" depth | 5.0 | 4.7 | 3.6 | 2.4 |
| | Mean 18" depth | 3.0 | 4.2 | 1.6 | 1.0 |
| | Number of peak tensions | 1 | 2 | 3 | 4 |
| Torrington | Mean 6" depth | 6.1 | 5.7 | 4.6 | 3.2 |
| | Mean 18" depth | 4.6 | 4.5 | 1.6 | 1.4 |
| | Number of peak tensions | 2 | 3 | 4 | 5 |

With the exception of a slight tension rise at 30 inches at Powell for the dry treatment, all other 30 inch and 42 inch readings remained at or near field capacity of about 0.3 atmosphere. Whenever the final reading for the season approached design levels for irrigation it was included in the seasonal mean. The existence of treatment differences, and tension rises at 18 inches for the dry treatments, is emphasized in Table 1. The relatively low 18 inch tensions at Worland reflect poor root development caused by a very heavy infestation of root rot. The small number of tension peaks for the Wheatland location were the result of a high water table through most of the growing season.

No significant differences between treatments were found for stand count, although the Worland data approached significance in the direction of increasing count with increasing moisture. Similarly, no significant differences were found for percentage of sugar. Table 2 presents the results for yield.

Table 2.—Yield Data and Number of Irrigations, 1952.

| Treatment | Powell | | Worland | | Wheatland | | Torrington | |
|---|---|---|---|---|---|---|---|---|
| | Yield | No. Irr. | Yield | No. Irr. | Yield | No. Irr. | Yield | No. Irr. |
| 8 atm (W-1) | 12.0 | 2 | 5.9 | 1 | 14.1 | 0 | 11.8 | 1 |
| 4 atm (W-2) | 14.7 | 3 | 9.3 | 4 | 14.2 | 1 | 14.4 | 2 |
| 2 atm (W-3) | 16.3 | 4 | 11.6 | 5 | 15.2 | 2 | 16.0 | 4 |
| 1 atm (W-4) | 17.3 | 6 | 12.3 | 6 | 15.0 | 4 | 16.3 | 4 |
| No. growers irr. | | 6 | | 4 | | 3 | | 5 |
| F-value (3.86 at 5%) (6.99 at 1%) | 8.62[1] | | 39.0[1] | | 0.94ns | | 27.1[1] | |
| LSD, 5% level | 2.5 | | 1.5 | | 1.7 | | 1.2 | |

[1] r = 0.606 significant at the 1 percent level.

In general, yields increased with increasing moisture, but differences were not significant for treatments with a mean value of about four atmospheres or less. Examination of detailed tension data showed that, whenever the mean of four replicate tensions rose to eight atmospheres at six

inches depth anytime during the season, a statistically significant yield reduction resulted. There were a number of late season tensions above eight atmospheres at six inches not evident in Table 1.

It has been suggested by plant pathologists that anaerobic conditions promoted by higher moisture levels could retard damage by rhizoctonia, and that this influence may be reflected in the improved stand count and higher yields at the Worland location. Analysis of variance on data combined for locations in 1952, and on data combined for locations and the years 1951 and 1952, showed no significant difference in yield between the one-atmosphere and the two-atmosphere treatments.

Consistent deviations from replicate means for some plots suggested the use of regression analysis of yield on moisture tension. Table 3 presents a tabulation of correlation coefficients for the regression lines.

**Table 3.—Correlation Coefficients of Yield on Mean of Peak Tensions.**

| Location | 6" depth | 18" depth |
|---|---|---|
| Powell | —0.832[2] | —0.427[1] |
| Worland | —0.855[2] | —0.716[2] |
| Wheatland | —0.504[1] | —0.642[2] |
| Torrington | —0.719[2] | —0.427ns |

[1] r = 0.482 significant at the 5% level
[2] r = 0.606 significant at the 1% level

The apparently better correlation for the 6 inch depths, already referred to, is obvious. The magnitude of the coefficients is supporting evidence that individual tension deviations for some plots were not a random variation. Examination of diagrams showed a broad scatter of points below about 4 atmospheres mean tension, indicating that the major part of the correlation was due to the drier plots.

**1953**

Irrigations during 1953 were scheduled on the basis of indicated mean tensions at the six-inch depth throughout the season. The three wet treatments were nominally the same—1 atmosphere (W-4), 2 atmosphere (W-3a), and 4 atmospheres (W-2)—but being based on the six-inch depth only, were in effect wetter treatments than previously used. Although it was apparent that yield reductions resulted from tensions of the order of eight atmospheres during the midportion of the growing season, additional information was wanted on the effect of high tensions after the peak water-use period had passed. To this end, treatment W-3b was initiated and irrigated at 2 atmospheres as W-3a until August 10 (peak use period in 1952 was the last week in July), at which time no further irrigations were made.

New locations were selected at both Powell and Torrington, with the same plot design and Bouyoucos block installations plus the addition of two extra units per plot at 6 inches in the row adjacent to the original 6 inch units. Tensions were calculated for 4 readings per plot and 16 readings per treatment. All plots received a uniform irrigation after units were installed.

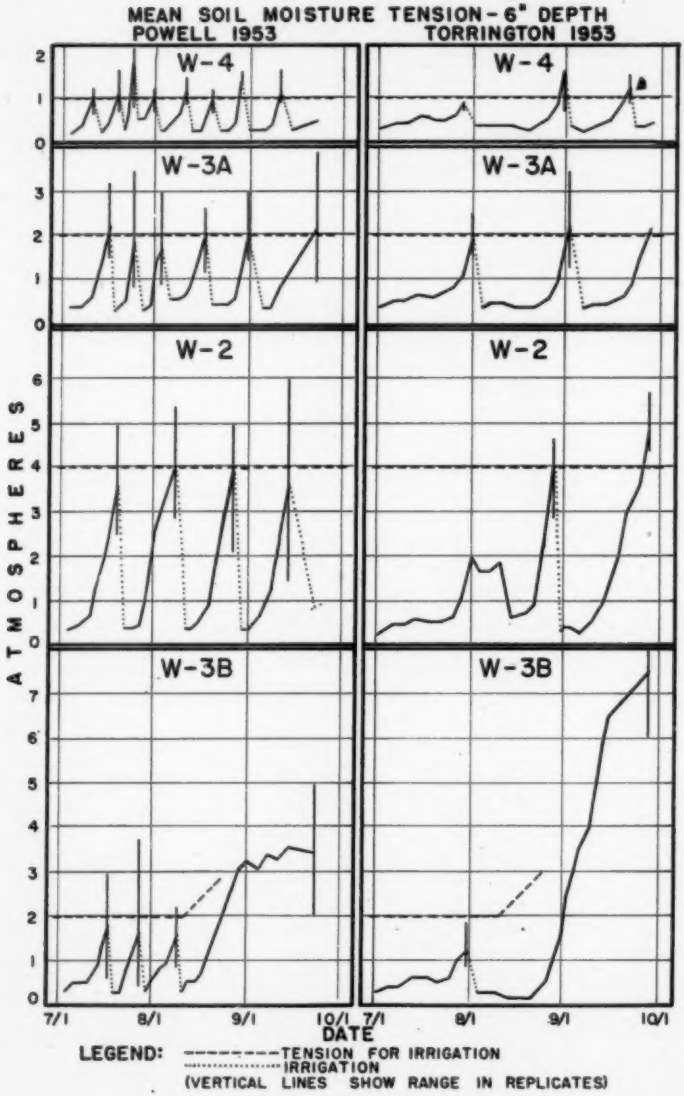


Figure 1—(left half of page)

Figure 2—(right half of page)

Figures 1 and 2 present the tension-time curves for the two locations. Plots were irrigated quite close to design mean tensions. The vertical line segments on the curves emphasize the considerable differences between replicates. The curves for the W-3b treatments are of particular interest. Following the August 10 irrigation-termination date, the tension at Powell rose to mean 3½ atmospheres by September 1 and remained approximately the same until harvest. The continued low tensions at 18 inches indicated a constant tension at 6 inches was not accounted for in increased subsoil moisture use, but the result of very low moisture use by the plants over this period. A similar effect was observed in consumptive use investigations on the 1952 data. On the other hand, Torrington shows a nearly linear tension rise until harvest.

It is believed that the continued cool and rainy weather that occurred during July retarded development of the plants so that the peak use period occurred after August 10, and the period of low moisture extraction did not occur before harvest. Treatments W-3b were directly comparable only to treatments W-3a and were analyzed as a paired comparison. Due to the low number of degrees of freedom, t-values were not significant. For Powell, treatment W-3b yielded 14.62 tons per acre against 13.45 tons per acre for treatment W-3a (2 atmospheres throughout the season), three out of the four replicates showing higher yields in favor of terminating irrigations on August 10. At Torrington, permitting the W-3b plots to dry to a mean value of 7.5 atmospheres by harvest reduced the yield from 19.72 to 17.72 and was consistent for all replicates. This reduction is considered to be real and, in view of field reports that tops died back to the ground two times, is surprisingly small.

Table 4 presents yield results for the 1 atmosphere, 2 atmosphere, and 4 atmosphere treatments maintained throughout the season.

**Table 4.—Yield Data and Number of Irrigations, 1953.**

| | Powell | | Torrington | | Locations |
|---|---|---|---|---|---|
| | Yield | No. Irr. | Yield | No. Irr. | Combined Yield |
| 4 atm (W-2) | 14.5 | 5 | 19.4 | 2 | 16.9 |
| 2 atm (W-3a) | 13.4 | 6 | 19.7 | 3 | 16.6 |
| 1 atm (W-4) | 14.1 | 9 | 19.5 | 4 | 16.8 |
| No. growers irr. | | 7 | | 5 | |
| F-value | 1.69ns | | 0.09ns | | 0.09ns |
| LSD, 5% level | 1.3 | | 1.9 | | 1.6 |

Neither a significant difference nor a consistent trend between yield and moisture tension was found over the range to 4 atmospheres.

The correlation coefficient for regression analysis was +0.551 for Powell (the 5 percent level for significance was 0.553), and —0.048 for Torrington. Far from showing a significant yield depression with increasing tensions, Powell nearly has a significant **increase** in yield with **increasing** tensions to 4 atmospheres.

**Combined Data—1952 and 1953**

A final analysis was made to determine whether tensions to four atmospheres significantly reduced yields. Because of different overall yield levels at the various locations, a regression analysis of combined field data would show a broad scatter even if the regressions for the individual locations had been perfect.

To make data comparable between locations, yields were expressed as a percentage of the mean yield for the replicate in which they were located. Since tension levels differed considerably between locations, and somewhat between replicates, they were recalculated as atmospheres tension above the lowest tension found within the replicate in which the plot was located. The transforms appear logical and were tested for all individual locations for 1952 and 1953. In every case negative correlation coefficients were increased, and the few positive coefficients were either numerically reduced, or converted to small negative values. If any bias exists it is toward increasing correlation. Data were discarded for 62 plots with a seasonal mean tension greater than 4 atmospheres, or with any peak tensions during the season in excess of 5.0 atmospheres. Using transformed data for the remaining 30 plots, a correlation coefficient of —0.204, and a regression slope of 1.06 percent yield per atmosphere tension were determined. The correlation coefficient was nonsignificant compared with the 5 percent level of 0.355, indicating that any yield effect due to moisture within the 4-atmosphere range was at best erratic. Had the correlation been perfect, the regression slope indicates that the maximum yield reduction due to tensions of four atmospheres, for an average yield of 15.94 tons per acre, would have been 1.2 tons per acre.

## Discussion

Additional information is needed to establish more definitely the particular horizon at which yield most closely correlated with soil-moisture tension. There is evidence on hand that this may be influenced by phosphate nutrition and by the height of the water table.

Certainly there is an immediate need to develop inexpensive instrumentation techniques, or visual relations, that will permit the grower to estimate the magnitude of soil moisture tension in his field, and the need for irrigation. It is apparent that accurate recommendations in terms of day intervals must account for soil differences, water table contributions, stage of growth, and climatological factors.

It is suggested that the absence of significant differences in many previour irrigation experiments based on percentage of moisture in the soil, or even the percentage of available moisture in the soil, may well have been the result of all treatments falling within the four-atmosphere range. It is within this range that the greatest changes in percentage of soil moisture occurs.

## Conclusions

1. Variability of data makes it questionable that treatment differences of less than 1.0 to 1.5 tons per acre could have been detected. Allowing this tolerance, the preponderance of information indicated that, under the conditions of this investigation, no yield reduction resulted for soil moisture tensions up to four atmospheres soil moisture tension at the six-inch depth.

2. There is definite and consistent yield reduction for soil moisture tensions of eight atmospheres at the six-inch depth.

3. Information to date would indicate that yield may be more frequently correlated with soil moisture tensions at the 6 inch depth than at the 18 inch depth or at a mean of the 6 inch and 18 inch depths.

4. A saving of two or three irrigations may be achieved by permitting the soil to dry to four atmospheres tension at the six-inch depth compared with irrigating at one atmosphere tension. At most of the locations investigated, irrigation practices of the commercial grower compared with the one atmosphere treatment.

# Progress Report on Irrigation Experiment— Rader Farm, Saginaw, Michigan

HAL B. REEVE AND ERNEST H. KIDDER[1]

This is a progress report on an experiment to determine the effects of supplemental irrigation on a soil-building rotation with sugar beets as one of the crops. The experiment is designed around a three-year rotation consisting of a small grain seeded to alfalfa, alfalfa used as a green manure crop with the first cutting left lying on the ground and second cutting allowed to grow through it with the entire growth, thus two cuttings being plowed under around August 15. Sugar beets are planted the following spring. Thus, one-third of the land area is devoted to the growing of alfalfa to be plowed under as a green manure crop.

For this experiment, an 18-acre area was divided into three six-acre fields. The soil was a Brookston loam, an excellent sugar beet soil. The field was tiled in 1949 at 4-rod intervals. Each field was again divided to compare rates of fertilization, the rates being 2,500 pounds of complete fertilizer on the high side and 1,250 pounds of complete fertilizer on the low side. The plots were further divided so that one-half of each fertilizer plot received supplemental overhead irrigation.

The fertilizer application by crops is shown in Table 1.

**Table 1.**

| Small Grains (Seeded) | | Alfalfa (Green Manure) | | Sugar Beets | |
|---|---|---|---|---|---|
| **High** | **Low** | **High** | **Low** | **High** | **Low** |
| 500 lbs. (4-16-16) | 500 lbs. (4-16-16) | 500 lbs. (Top Dressed) (0-20-20) | 0 | 250 lbs. (4-16-16+B)[1] 1250 lbs. (0-20-20) | 250 lbs. (4-16-16+B) 500 lbs. (0-20-20) |

[1] 5 percent Borax

In 1953, the fertilizer application was changed so that additional fertilizer was applied on the small grain and less on the sugar beets as shown in Table 2.

**Table 2.**

| Small Grains (Seeded) | | Alfalfa (Green Manure) | | Sugar Beets | |
|---|---|---|---|---|---|
| **High** | **Low** | **High** | **Low** | **High** | **Low** |
| 1500 lbs. (5-20-20) | 750 lbs. (5-20-20) | 500 lbs. (0-20-20) | 0 | 250 lbs. (5-20-20+B)[1] 250 lbs. (0-20-20) | 250 lbs. (5-20-20+B) |

[1] 5 percent Borax

Bouyoucos moisture blocks were placed at 5 inch and 10 inch depths in all crops. When these moisture blocks indicated an available soil moisture

[1] Agriculturalist, Farmers & Manufacturers Beet Sugar Association, Saginaw, Michigan, and Associate Professor, Agricultural Engineering, Michigan State College, East Lansing, Michigan, respectively.

content of 50 percent or less, irrigation was applied with an overhead sprinkling system as shown in Figure 1. In 1950, irrigations were made on the oats on June 19-23 and July 9-11. Sugar beets were irrigated July 9-11 and August 24 and 25. It should be pointed out that each irrigation preceded a good rain by only a few days.

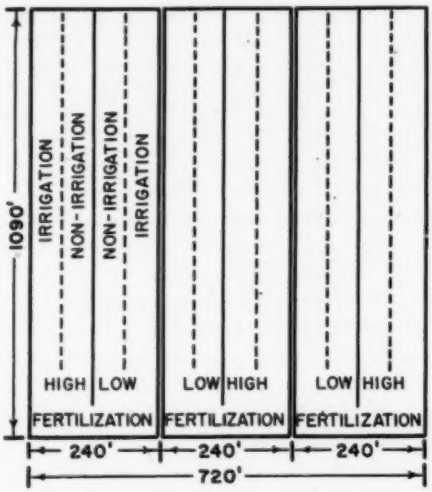


**Figure 1.—Field layout.**

Oats were harvested with a combine and sack samples taken. Since there was no difference in treatment this first year, the irrigated plots were averaged together and yielded 57 bushels per ace, while the non-irigated plots averaged 67 bushels per acre. No visual difference could be noted in the standing grain with the possible exception of increased incidence of rust in the irrigated area.

**Table 3.—Irrigation Statistical Summary for Sugar Beets, Rader Farm, 1950.**

| | High Fertility | Low Fertility | Difference Required for Significance at the 5% Level |
|---|---|---|---|
| Tons/Acre | 19.65 | 19.05 | 1.53 |
| Sucrose Percent | 16.30 | 16.21 | 1.09 |
| Gross Sugar | 6410 | 6176 | 728 |
| | **Irrigated** | **Non-Irrigated** | |
| Tons/Acre | 18.66 | 20.04 | 1.53 |
| Sucrose Percent | 16.22 | 16.29 | 1.09 |
| Gross Sugar | 6057 | 6530 | 728 |

| | High Fertility | | Low Fertility | | |
|---|---|---|---|---|---|
| | Irrigated | Non-Irrigated | Irrigated | Non-Irrigated | |
| Tons/Acre | 19.30 | 20.00 | 18.03 | 20.08 | 2.17 |
| Sucrose Percent | 16.38 | 16.22 | 16.08 | 16.35 | 2.56 |
| Gross Sugar | 6312 | 6509 | 5802 | 6550 | 1033 |

Sugar beets were harvested with a Scott-Urschel sugar beet combine in one-row strips for the length of each plot (1,090 feet). The statistical summary is presented in Table 3.

The yields of alfalfa were not taken. It was felt that any benefit from the extra fertilization or irrigation on the alfalfa should be measured in terms of increased yields in the following crops of sugar beets and oats.

The same procedures were followed and the same general results secured in 1951 and 1952. The yields were the same in all treatments. In the sugar beet plots, however, it was observed that more disease in the form of root rot during the summer was occurring in the irrigated plots. This disease was probably a factor in offsetting any yield benefits from the extra fertilizer and/or irrigation. The stand of sugar beets on the irrigated plots at harvest time averaged about 25 percent less than the non-irrigated plots.

In 1952, ½ inch of water was applied to the sugar beet irrigation plots prior to emergence due to extremely dry soil conditions. These plots emerged 10 days sooner than the non-irrigated plots.

In 1952, irrigation was not applied until the Bouyoucos moisture blocks gave an indicated moisture content of 20 percent or less.

During this three-year period it was further observed that at no time did the sugar beets appear to be suffering for the lack of moisture even though the soil moisture content at the 10 inch depth got below the 20 percent level.

In 1953, Bouyoucos moisture blocks were placed at 6 inch, 12 inch, 24 inch and 36 inch depths. Adequate moisture was received until August, followed by a rather dry August and September. The rainfall for this period is shown in Table 4.

**Table 4.**

| 1953 | | | |
|---|---|---|---|
| August | 7 and 8 | 1.96" | |
| | 12 | .04 | |
| | 21 | .07 | |
| | Total | | 2.07" |
| September | 4 | .45 | |
| | 6 | .05 | |
| | 12 | .56 | |
| | 19 | 1.20 | |
| | 26 | .83 | |
| | Total | | 3.09" |
| October | 4 | .48 | |
| | 6 | .30 | |
| | 27 | .37 | |
| | Total | | 1.15" |

## Conclusion

By the 20th of August, moisture blocks in the sugar beet plots gave an indicated available moisture content reading of 0 percent at the 6 inch depth. By the 15th of September, all moisture blocks in the sugar beet

plots read zero with the exception of the 36 inch depth. The moisture reading at the 36 inch depth remained at a 100 percent level throughout the entire growing season. Again it was observed that at no time did the sugar beets show any symptoms of suffering for the lack of moisture throughout the 1953 growing season. No supplemental irrigation was applied to any crop during the 1953 season. Very little root rot was evident in the sugar beet plots in 1953.

From Table 4, you will note that during 1953 the last heavy rains occurred on August 7 and 8. A rainfall of 1.20 inches fell on September 19. However, the ground was so dry that this moisture did not penetrate much below the 5 inch depth. Four rows in each treatment were harvested with a Marbeet Midget harvester and loaded directly into trucks to obtain yield results in 1953.

The yields obtained are shown in Table 5.

**Table 5.**

| | High Fertilization | Low Fertilization |
|---|---|---|
| Tons/Acre | 15.22 | 15.20 |
| Tons/Acre | 13.78 | 14.52 |
| | 14.58 | 14.86 |

1. No increased yields have been secured to date from extra fertilization or supplemental irrigation.

2. Supplemental irrigation as applied to the sugar beets caused excessive root rot during the summer. Harvest stands in the irrigated plots were reduced by as much as 25 percent.

3. Early irrigations to get the beets up and off to a good start may be more important in normal years than late summer irrigations.

4. Sugar beets have the ability to draw moisture from the subsoil when no moisture is available in the surface area.

5. At no time during the growing season of 1950, 1951, 1952 and 1953 did the soil moisture get low enough to cause excessive wilting of the beet leaves as often occurs in the irrigated areas of the west.

6. It would appear that too much moisture may be more of a factor for decreased yields in this area than a lack of moisture when the soils are high in organic matter and adequate amounts of commercial fertilizer are used in the rotation.

# The Control of Annual Grasses in Sugar Beets With Dalapon

L. E. WARREN[1]

Weed control usually accounts for a large proportion of the expense incurred by the grower in raising a crop of sugar beets. Annual grasses, because of the nature and vigor of growth, present the most difficult problem. Hand-blocking and thinning costs are increased considerably; indeed, thinning crews have refused to work in some fields because of the dense stand of grass. Even after the grass has been cleaned up at thinning time a new crop often comes back following irrigations, necessitating continued hoeing costs through the season. Mechanical blocking, of course, will reduce the grass population depending on the method used but many small grass seedlings still remain in the block of beets.

Recently chemicals have been used to alleviate this burden of weed control. Pre-emergence sprays which kill by contact have been applied a few days ahead of emergence of the beets; ideally, this kills all weed foliage above ground. Chemical residues which injure the beet seedlings emerging later have been a problem with this treatment.

Sodium TCA is another chemical being used successfully in some areas to control annual grasses. Since TCA acts through the soil, the success of this treatment depends on the proper amount of rainfall or sprinkling following application to carry the toxicant into the soil.

In searching for new selective chemicals it has been recognized that a treatment applied after emergence of the weeds and crop is more desirable than pre-emergence type sprays. Some of the advantages to be realized with this type of control are: 1. The grower can evaluate the weed population before treating. 2. He can wait for emergence of the beets. 3. If weeds are not general, "spot spraying" is possible.

Toxic materials, to be active on the growing plants, could be absorbed through the roots as with TCA, or through the leaves or through both, as occurs with 2,4-D on broadleaved plants. Of course, translocation of the compound must carry it to a point within the plant where the biological processes will be disturbed sufficiently to cause death or severe inhibition. TCA, which is absorbed through the roots, can be effective against young grasses after emergence if proper rainfall occurs to carry it to the root zone of the grasses in lethal quantities. However, there is a risk, except with artificial rainfall, that the material will not be leached into the soil until too late to control the grass, or that it will be leached too deep to be effective.

Recently a chemical that is absorbed and translocated downward through the blades of grasses was discovered (1).[2] It has been given the name "dalapon." The compound is 2,2-dichloropropionic acid. It may be interesting to note the structure of the sodium salt of dalapon (furnished to

---

[1] The Dow Chemical Company, Seal Beach, California.
[2] Numbers in parentheses refer to literature cited.

experiment stations in 1953) compared to the sodium salt of TCA. Sodium TCA is $Cl_3CCOONa$. Sodium dalapon is $CH_3Cl_2CCOONa$. Except for the substitution of a methyl group for a chlorine atom on the No. 2 carbon, these compounds are the same. Yet TCA can be absorbed through the roots only whereas dalapon is absorbed through both leaves and roots. Dalapon has been found by results of single oral acute experiments to be less toxic to warm-blooded animals than table salt. The sodium salt, which will be the first formulation to be marketed, is readily soluble in water.

At the rates required for annual grass control, contact burn usually does not occur; however, it may develop on the margins of both broadleaves and grasses under conditions of high temperature. The killing action on grasses is first manifested 2 to 3 weeks after spraying as necrosis of blade margins, which gradually progresses downward to the crown of the plant in 7 weeks. This is the time usually required for ultimate kill, although young seedling grasses may succumb in 3 to 4 weeks.

One of the first crops considered for selective treatments with this chemical was sugar beets. The first applications were made in the summer of 1952 to beets in various growth stages where watergrass was a problem. Observations of these plots indicated the following: 1. The dosage for control of grasses was in the range of 3 to 6 pounds per acre. 2. Although the beet top growth was suppressed for a few weeks, at harvest time there were no observable differences between the treated and untreated plots.

With this encouragement, plans for the 1953 season were made to confirm the findings of our 1952 work and in addition to determine: 1. Effect of dalapon on the yield of beets. 2. Optimum volume rate. 3. Relationship of growth stage of grasses to dosage. 4. Effect of environmental conditions such as temperature and soil moisture.

The yield plots were uniform beets which received normal culture including good non-chemical weed control. Applications were made at two growth stages—just after thinning and about 5 weeks later—both as separate and repeat sprays. One experiment was applied to beets in the 2-leaf stage with the second and repeat sprays after thinning. Two or three samples per plot were collected for sucrose analysis and processed by the appropriate company laboratories.

The dosage required for control of watergrass under conditions favorable to the action of dalapon is in the range of 3 to 5 pounds sodium salt per acre, as shown in Table 1.

The dosage rates specified are based on excellent wetting (film type) of grass blades. It has been found that dalapon is much more efficient with

**Table 1.—Control of Watergrass in Sugar Beets with Dalapon.**

| Sodium dalapon lbs. per acre | Estimated % control Expt. 1 | Expt. 2 |
|---|---|---|
| 2.3 | 84 | 83 |
| 3.5 | 96 | |
| 4.7 | 92 | 93 |
| 7.0 | 99 | |

a good surfactant. Curves (Figure 1) have been drawn for another experiment, which show the improvement in action of dalapon at a given dosage per acre with good wetting action after 27 days.

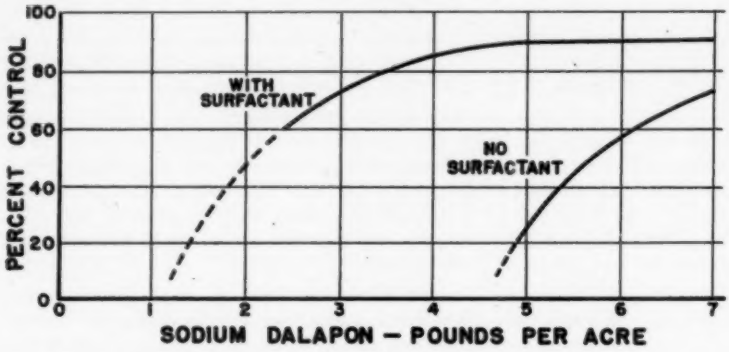


**Figure 1.—Effect of surfactants on action of dalapon.**

In Table 2 we can see that the controls at given dosages are essentially equal at three growth stages from seedling to stooling. Experiments 1 and 2 were immediately adjacent; 3 was in another field but in all three the beets, and consequently the grasses, were maintained in good growth during the season. The information on temperatures shows that over this range there is no apparent difference in the control of grasses.

**Table 2.—Effect of Temperature and Size of Grass on Control with Sodium Dalapon.**

| Grass growth<br>Temperature[1]<br>Lbs. per acre | 1-3 leaves<br>65-87° F | Several leaves<br>69-84° F | Stooled<br>100° F |
|---|---|---|---|
| 2.3 | 84 | 83 | 81 |
| 3.5 | 96 | | 90 |
| 4.7 | 92 | 93 | 95 |
| 7.0 | 99 | | 98 |

[1] Maximum temperature range during first week.

The influence of soil moisture on control was indicated in an experiment in which, at the time of the first application and for a few days afterwards, the grower withheld irrigation to retard the growth of the grass. This was effective in reducing the vigor of the grass. Very poor control with dalapon occurred, which may have been because the grasses were under moisture stress.

Results of tests to determine the optimum volume rate for dalapon sprays revealed no differences in the range of 100 to 12.5 gpa, as shown in Table 3. In selecting the rate of surfactant to be used in the volume rate tests, it was decided to use an intermediate scale between percent solution and constant amount per acre.

Table 3.—A Comparison of Volume Rates Using Dalapon in Grass Contol.

| Sodium dalapon Lbs. per acre | Gallons per acre | | | | |
|---|---|---|---|---|---|
| | 100 | 75 | 50 | 25 | 12.5 |
| 3.5 | 87 | 96 | 79 | 83 | 70 |
| 4.7 | 96 | 92 | 88 | 91 | 93 |

The results of studies to determine whether dalapon influences the yield of sugar beets are summarized in Table 4. It is readily seen that sucrose percentage is not affected by any of these treatments. Neither does the wetting agent influence any of the results. Therefore, the only consideration is the effect of dalapon on the size of the beets. Analyses of variange of these data indicate that the following treatments may reduce sugar beet yields significantly; 1. Rates over 4 pounds sodium dalapon per acre. 2. Repeat applications of 4 pounds or more per acre each time.

Table 4.—Effect of Sodium Dalapon on Yield of Sugar Beets.

| Time of application | Sodium dalapon Lbs. per acre | Results — plot means | | | |
|---|---|---|---|---|---|
| | | Expt. 1 | | Expt. 2 | |
| | | Yield[1] pounds | Percent sucrose | Yield[2] pounds | Percent sucrose |
| 2 wks. after thinning | 2 | 637 | 14.4 | 404 | 13.5 |
| 2 wks. after thinning | 4 | 605 | 14.3 | 373 | 13.1 |
| 2 wks. after thinning | 6 | 556[3] | 14.3 | 336[4] | 12.7 |
| 7 wks. after thinning | 4 | 584 | 14.4 | 390 | 14.0 |
| 7 wks. after thinning | 6 | 568 | 14.2 | 341[4] | 12.3 |
| Both times | 4.+ 4.7 | 579 | 14.1 | 316[4] | 12.7 |
| Both times | 6 + 7.0 | 491[4] | 14.6 | 290[4] | 12.6 |
| Untreated | ——— | 634 | 14.6 | 425 | 13.6 |

[1] 5 percent L.S.D. = 68; 1 percent L.S.D. = 91
[2] 5 percent L.S.D. = 55; 1 percent L.S.D. = 74
[3] = significant at 5 percent level
[4] = significant at 1 percent level.

The degree to which the beets will recover from dalapon treatments appears to be a function of time to harvest. Therefore, it may be advantageous to allow as much time as possible after treatment before digging the crop. Beets in seedling stage are not more sensitive than at later periods.

Although the work reported here in connection with sugar beets is concerned with only water grass (*Echinochloa crusgalli*), research on other projects indicates that a wide variety of annual grasses, both winter and summer, can be controlled with the dosages of dalapon specified above. Factors relating to environment, surfactants, volume rates, etc., appear to apply as well to these other species.

The influence of environmental factors such as temperature, soil and air moisture and soil fertility appears to be important because they influence the growth conditions of the grasses. It seems reasonable that translocation and assimilation would be faster and more effective when the plant is growing vigorously, as is found with 2,4-D on broadleaved plants. There-

fore, it may be desirable to apply dalapon during periods of vigorous grass growth. If soil moisture is adequate and other environmental factors are favorable, growth is most rapid from seedling to early stooling of the grass. Practices which maintain the beets in good growing condition would favor the grass as well, so the cultural operations would not need to be changed to accommodate the dalapon application.

Undoubtedly applications should not be made a few days before or after blocking and thinning because of the stress this disturbance places on the young beets.

Although observations to date indicate that temperature does not influence action of dalapon except to cause marginal leaf burn in hot weather, it is quite possible that a temperature stress may reduce the control.

The yield data indicate that care will have to be exercised in applying dalapon to sugar beets. Since these were overall sprays, it is difficult to determine whether dalapon is absorbed by the beet more readily through the leaves or the roots. Surface irrigation following application would carry chemical on the soil surface into the root zone easily. However, in the first two experiments, the beet leaves at the second application formed a nearly complete canopy over the soil surface. Therefore, since most of the spray probably remained on the leaves, and the yields at this time were reduced as much as or more than earlier treatments, it can be assumed that dalapon is absorbed through beet foliage in sufficient amounts to affect growth.

Although dalapon is undoubtedly absorbed through the foliage of beets, it was evident that yields were equal whether or not a wetting agent was included in the sprays. Undoubtedly, this is because plain water carriers spread readily over the beet leaves and the wetting agent does not decidedly enhance either the spreading or penetrating qualities of the dalapon solution. Therefore, since it has been shown that good surface active agents improve the action of dalapon on grasses, it is desirable to use a good wetting spray for this application.

Because of the reduction in yield with over 4 pounds of dalapon per acre, it becomes desirable to consider the effect of treatments using 2 to 4 pounds. Figure 1 shows that good control is possible with dosages of 3 pounds per acre. Two pounds per acre could be quite effective in relieving the strain on the thinning crew. Where later germination of grasses is likely, a timely application of 3 pounds of dalapon to the later crop of grass may benefit the beets more than an earlier treatment. It is possible that treatment of seedling grass at sub-lethal but growth retarding rates followed by sprays of lethal dosages on regrowth of the grass would provide effective control and still not reduce the beet yield.

Other possibilities of reducing the effect dalapon might have on the crop include placed sprays. The beets are shielded and/or the spray directed to contact only as much of the beet plants as is necessary to cover the grasses adequately. Good application techniques are always important and here, in addition to the types of spraying mentioned above, it is desirable to attempt the best possible coverage of the weeds. Reasonably fine sprays usually accomplish this purpose best.

Conclusions reached from data available are as follows:

1. Dosage of 3 to 4 pounds sodium dalapon per acre was required for control of watergrass. (Research is necessary on other grasses.)

2. When grasses were growing well, dosage required was same from seedling to early stooling stage.

3. Above dosage rates assume excellent wetting of grasses.

4. Maximum effect of dalapon on grasses required 6 to 8 weeks.

5. Severe soil moisture stress reduced grass control.

6. Temperature in range of 55° F. to 100° F. had no effect on control.

7. Controls were same for volume rates from 100 to 12.5 gpa.

8. Addition of surfactant did not affect yield.

9. Sucrose percentage was not affected by dalapon at 2 to 7 pounds per acre.

10. Yields were reduced by sodium dalapon applied as follows:

a. More than 4 pounds per acre.

b. More than one application of 4 pounds or more per acre.

Much more research is necessary before dalapon can be recommended to control grasses in sugar beets. Some of these projects are as follows:

1. Effect of sodium dalapon at 2 to 4 pounds per acre on yield. (Higher rates may be desirable in some areas.)

2. Use of placed and shielded sprays.

3. Relationship of volume rate to control and yields.

4. Influence of various times between treatment and harvest.

5. More data on effects of environmental factors, particularly growth stresses on control and yield.

6. More data on value of repeat sprays to control:

a. The first crop of grass to be treated.

b. Succeeding germinations of grasses.

7. Effect of dalapon in the soil on germinating beet seedlings.

8. Presence or absence of dalapon residue in soil and crop at harvest.

9. Differences of beet varieties in response to dalapon.

10. Best types of surfactants.

Dalapon will be recommended in 1954 only for non-crop grass control. It will be marketed as the sodium salt with some wetting agent added. Under some circumstances this may be insufficient to provide the best wetting and additional surfactants will be desirable. Experimental formulations of sodium dalapon without wetting agent will be available for research purposes.

## Literature Cited

(1) Dalapon Bulletins Nos. 1 and 22, The Dow Chemical Company.

# Grass Control in Sugar Beet with the Herbicides IPC, TCA and DCU

R. T. NELSON[1]

## IPC

Preliminary work showed IPC to be safe on sugar beets only at rather low rates. Early investigations of Deming (2)[2] showed a crop of sugar beets survived a rate of 10 pounds per acre isopropyl-N-phenylcarbamate (IPC) with only a partial loss in stand. Final yield was not affected when an average seeding rate was used. Deming (2) received control of both mono- and dicotyledonous weeds. The writer (3) (4) (5) found IPC to be particularly effective in controlling wild oats and volunteer grain which included barley, oats and wheat. Good control of these weeds was obtained at a rate of 3 to 6 pounds per acre technical IPC. The IPC gave better control, and was less injurious to sugar beets than isopropyl-N-(3 chlorophenyl) carbamate.

The Great Western Sugar Company used IPC commercially on 4,800 acres of sugar beets during the spring of 1953. Recommendations by the company to growers were to spray IPC at the rate of 3 pounds per acre, and double disc material into soil immediately for the control of wild oats and volunteer grain, only. Final seedbed preparation and planting of sugar beets was to follow as soon as practical. Results were good. In fact, results were spectacular enough to reveal any inefficiency in application or incorporation of chemical into soil. See Figure 1.

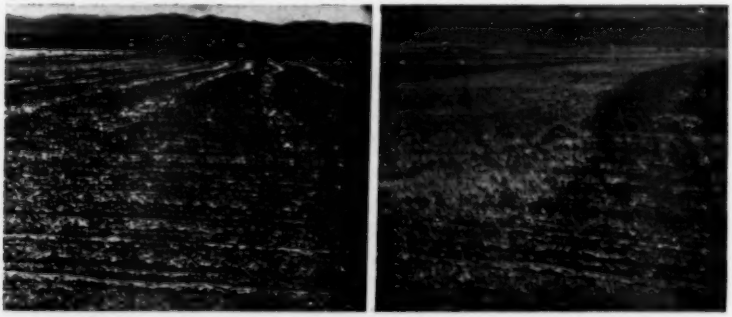

**Figure 1.—Wild oats appearing as strips in sugar beet field treated at an average rate of three pounds IPC per acre. Right: The farmer claims inadequate mixing in sprayer before starting to spray was responsible for wide grassy strip. Left: Lower side of same field where farmer had corrected his fault in spraying; however, strips indicate skips in incorporation of IPC with soil since strips follow direction of discing and not direction of travel in spraying.**

---

[1] Agronomist, the Great Western Sugar Company, agricultural experiment station, Longmont, Colorado.

[2] Numbers in parentheses refer to literature cited.

One test was made at Longmont, Colo., to find what influence date of application of IPC might have on results. Applications were made at about 2-week intervals starting February 3, and ending May 14. Using barley as the test plant, and a standard rate of 3 pounds per acre IPC, good practical control was obtained from all dates of application. Soil moisture content and soil temperature were obtained at each time of application. Moisture content varied from 5 to 13 percent, and temperature from 41° to 59° F. With the exception of the February 14 date of application, soil temperature at the 1- to 2-inch depth was within the range of 55° to 59° F. In this test the later applications gave slightly better control and were accompanied by more moisture.

In commercial use it was observed that IPC was more phytotoxic under conditions of warm temperature and good growing conditions. During cool temperatures the apparent action of IPC on plants was slow; however, under these conditions the persistence of IPC in the soil was much prolonged. The final control obtained with IPC was satisfactory even under cool temperatures, although there was a period in which it was questionable whether control would be satisfactory. In many instances during the spring of 1953 the wild oats and grain emerged and later died. This was a new experience since, in experimental trials conducted during 1951 and 1952, these weeds usually died before reaching the surface of the soil. The eventual kill of emerged weeds was accompanied by warm temperatures and drying winds. Apparently, under these conditions, the restricted root system of the weeds did not provide adequate absorption of water to keep them alive. The emergence of the weed is proof that the level of IPC in the soil is inadequate under the existing conditions. Thus, in view of the lower activity of IPC under cool temperatures, rates of 3 to 5 pounds per acre might be considered by some growers making early application, especially if the price of IPC is reduced so that chemical control at the higher rates would compete with other means of control. At the present prices of IPC, the rate of 3 pounds per acre does give fairly economical control, and the percentage control has usually been more than 85 percent.

Injury to sugar beets by IPC applications at the 3-pound per acre rate was negligible. In one case where IPC application was late (April 30), and the farmer had an unusually hard seedbed so that discing was only 2½ inches, there was noticeable retardation in growth of sugar beets in the early seedling stage. By thinning time, there was no apparent difference.

During sunny weather it is especially important to incorporate IPC into the soil immediately after spraying, plus immediate refirming of soil to prevent loss by volatilization. Loss of IPC at temperatures of 85° to 88° F. was found to be about 80 percent within a 24-hour period by Anderson, et al. (1) when spread as a thin layer.

## TCA and DCU

Eight field tests were initiated in the spring of 1953 to compare the effectiveness of TCA and DCU for control of foxtail (*Setaria*) and barnyard grass (*Echinochloa*). These followed tests in the greenhouse which

showed DCU to be effective when mixed with the surface soil for control of grass. Grass control with DCU was independent of direction of moisture movement in the soil. See Figure 2.

**Figure 2.—Test showing control of green foxtail grass *(setaria)* with DCU without stunting broadleaf weeds or sugar beets. Treatments: left to right—0, 10, 20 and 40 pounds of 73 percent active formulation of DCU applied as a spray and incorporated in surface soil to a depth of 1 inch. Foreground flats, sprinkle irrigated. Background flats, subirrigated.**

Tests were made in Colorado, Wyoming and Montana. Rates of 7.3 pounds per acre technical dichloral urea (DCU) and 7.2 pounds per acre acid equivalent of sodium trichloroacetate (TCA) were used. In some tests a rate of 14.6 pounds per acre DCU was used, also. The DCU used was a wettable powder, and was applied in water suspension at a volume equivalent to 20 gallons per acre. Plots were 28x400 feet in size. All treated plots were bordered on both sides by a check plot. The herbicides were applied as a spray prior to planting, and worked into the soil by shallow discing or harrowing. The control of grass was good on all treated plots except in the case of one test. In this test the control with DCU was excellent, while TCA gave no visible control. The test just referred to was started March 26, while other tests in the same district were applied approximately one month later. The DCU, being water insoluble, apparently stayed in the effective soil layer during April and May when most of the grass seeds germinated. Grasses surviving on DCU plots were malformed, and lacked vigor through June. Grass seedlings starting in July appeared normal; however, they succumbed to shading by the dense beet foliage at that time.

At rates used, TCA was more injurious to sugar beets than DCU. This is indicated in pre-thinning stand counts on one field. There was no indication in any of the tests that the chemicals might adversely affect yield. It was expected that in one field which was especially foul with foxtail grass a yield increase would be obtained on the treated plots. This was substantiated in harvest results obtained for Location 15, and reported in Table 1.

**Table 1.—Stand, Yield and Percentage Sugar of Sugar Beets Grown on DCU and TCA Treated Plots.**

| Treatment | Beets Per 100 Inches Pre-thinning Count | Beets Per 100 Feet Harvest Count | Tons Per Acre Beets | Percent Sugar |
|---|---|---|---|---|
| | **Location 15, Loveland, Colo.** | | | |
| DCU 7.3 lbs./A. | 22.0 | 68 | 13.3[1] | 15.3 |
| DCU 14.6 lbs./A. | 27.1 | 71 | 14.9 | 15.7 |
| TCA 7.2 lbs./A. | 17.6 | 66 | 13.4 | 15.5 |
| Check | 23.3 | 57 | 11.4 | 15.5 |
| LSD 5% pt. | 6.4 | — | 1.7 | NS |
| LSD 1% pt. | NS | — | 2.3 | — |
| | **Location 16, Longmont, Colo.** | | | |
| DCU 7.3 lbs./A. | — | 91 | 16.5 | 13.4 |
| DCU 14.6 lbs./A. | — | 101 | 16.8 | 12.8 |
| TCA 7.2 lbs./A. | — | 102 | 17.9 | 13.2 |
| Check | — | 91 | 16.3 | 13.3 |
| LSD 5% pt. | | — | NS | NS |

[1] Weights of paired samples of beets grown on treated and untreated soil were adjusted proportionately for local area affected by an obvious variation in field. Most of area within test was uniform, and thus only a single check value is carried.
NS = no significant differences at indicated level.

Location 16, sampled for yield and sugar, showed no significant difference in yield, Table 1. The latter field was practically free of weeds all season, and use of herbicides under such conditions would not have been expected to be beneficial.

The commercial use of TCA on a limited scale during 1950 through 1953 in territories served by the Great Western Sugar Company has indicated that 5 pounds per acre TCA, acid equivalent, is about the highest rate one might advocate for use on sugar beets of this area. Even then injury has occurred on occasions, and in other cases no effect on beets or weeds has been noticeable.

## Summary

In tests and in commercial use IPC has been found to give effective control on wild oats and volunteer grain in at least 85 percent of all cases, as observed in areas within Colorado, Wyoming and Montana served by the Great Western Sugar Company. General usage to date, which included 4,800 acres treated in the spring of 1953, has been to apply as a spray 3 pounds per acre technical IPC during seedbed preparation, and double discing to a depth of 3 to 4 inches immediately after application. Final seedbed preparation and planting of sugar beets followed as soon as practical.

Tests using TCA and DCU were made to compare effectiveness of treatments in controlling foxtail and barnyard grass. Applications of TCA at 7.2 pound per acre, and DCU at 7.3 and 14.6 pounds per acre, were made prior to planting, and chemicals incorporated with soil surface by harrowing or shallow discing. In most tests TCA and DCU controlled foxtail grass equally well. Under conditions where TCA failed to controll grass DCU gave good control. DCU was less injurious to sugar beets than TCA. In

the limited commercial use of TCA a rate of 5 pounds per acre, acid equivalent, is about the upper rate one might advocate for use within areas observed, including parts of western Nebraska, Colorado and Montana.

## Literature Cited

(1) ANDERSON, W. POWELL, LINDER, PAUL J. and MITCHELL, JOHN W.
1952. Evaporation of some plant growth regulators and its possible effect on their activity. Science 116:502-503.

(2) DEMING, G. W.
1950. Use of IPC for weed control in sugar beets. Proc. Amer. Soc. Sugar Beet Tech. 453-455.

(3) NELSON, R. T.
1951. Some results on chemical weed control. Through the Leaves 39 (5) :41-44.

(4) NELSON, R. T.
1952. Trials with herbicides for weed control in sugar beets. Proc. Amer. Soc. Sugar Beet Tech. 121-125.

(5) NELSON, R. T.
1953. Observations on commercial use of IPC. Through the Leaves 41 (4) :16-19.

# Pre-Emergence Applications of a Combination of TCA and Endothal Show Promise for Control of Grassy and Broadleaf Weeds in Sugar Beets

C. E. CORMANY[1]

**Abstract**

Pre-emergence use of Sodium TCA has been effective in controlling grassy weeds such as barnyard grass and the foxtails but has had little effect on the broadleaf weeds. Pre-emergence application of Endothal has shown promise for controlling broadleaf weeds such as rough pigweed and dwarf mallow, with little effect on the grassy weeds.

A combination pre-emergence spray, applying 7 pounds sodium TCA and 5 pounds Endothal per acre, in 1953 showed slightly better control for grassy and broadleaf weeds than for either alone. It was significantly better for total weed control than either alone. Sprays containing Endothal have depressed pre-thinned beet stands somewhat.

Endothal at 7 pounds technical per acre has been very effective in controlling dwarf mallow *(Malva rotundifolia)* on isolation plots used for seed production from steckling and mother beet roots.

[1] Chief Agronomist, Holly Sugar Corporation, Sheridan, Wyoming.

# Results with IPC Spraying in Eastern Montana

E. G. ECKROTH[1]

**Abstract**

In eastern Montana, variable results were obtained from spraying IPC for control of wild oats. The rate of application consisted of four pounds of IPC mixed with sufficient diesel fuel to amount to seven gallons of this mixture per acre. A detailed study of the effectiveness of IPC showed that, on the average, approximately 50 percent control was achieved.

[1] Associate Agronomist, Holly Sugar Corporation, Sidney, Mont.

# The Use of Chemical Additives to Control Soil Crusting and Increase Emergence of Sugar Beet Seedlings[1]

BRUCE L. BAIRD, JOSEPH J. BONNEMANN AND ARCH W. RICHARDS[2]

During the past three years there has been considerable widespread interest concerning the possibilities of using chemical additives to improve the physical conditions of soils. The chemicals have the one direct effect of increasing the stability of soil aggregates, which in turn affects pore space, permeability, surface crusting, etc. This report is concerned primarily with the value of a few of the numerous chemical additives for controlling soil crusting and increasing the emergence of sugar beet seedlings.

There has been a very limited amount of literature in technical publications to date reporting the value of additives for increasing emergence of plant seedlings. In a report summarizing the status of early research work with soil additives Martin (3)[3] noted that one-fifth pound of active conditioner per hundred square feet prevented serious crusting and greatly facilitated the emergence of bean seedlings and other vegetable crops. Others have made a similar observation (1) (4), but usually without reporting actual experimental results.

A problem of crusting exists, particularly on clay soil. There are approximately 55,000 acres of irrigated land on the Belle Fourche irrigation project in western South Dakota, two-thirds of which is a clay or clay loam soil. Sugar beets are grown commercially in the area and in some seasons the poor emergence of sugar beets is attributed to crusting.

The information in this report was obtained from stand counts of sugar beets in five trials conducted in 1952 and 1953. In three of these trials the emergence data were obtained as a part of field experiments designed to study early growth and production as affected by moisture x additive or fertility x additive. The last two trials were conducted to study emergence only. No discussion is made of the value of commercial fertilizer to increase emergence, early growth or production of the sugar beets even though such was a part of the trials conducted. A discussion of the response of sugar beets to fertilization in this area can be found in studies previously reported (2), (5), (6).

---

[1] Contribution of the Soil and Water Conservation Research Branch, ARS, USDA, in cooperation with the South Dakota Agricultural Experiment Station and the Utah-Idaho Sugar Company. The Monsanto Chemical Company supplied the Krilium-6 (partial calcium salt of Vinyl acetate-maleic acid) hereinafter referred to as VAMA, the Krilium-9 (sodium salt of hydrolized polyacronitrile) hereinafter referred to as HPAN, and the polymer 212-100D (co-polymer of isobutylene and the half ammonium salt-half amide of maleic acid) hereinafter referred to as IBMA. The Hercules Powder Company supplied the cellulose gum 120H (sodium carboxymethylcellulose, high viscosity cellulose gum) hereinatfer referred to as CMC. The names Krilium, polymer 212-100D, and cellulose gum 120H are supplied here only so that available data can be reported factually and the USDA does not guarantee or warrant the products. This does not imply approval of these products to the exclusion of others which might also be suitable.

[2] Soil Scientist, Agronomist (Agent), Western Section of Soil and Water Management, Soil and Water Conservation Research Branch, ARS, USDA, Newell, S. Dak., and Research Asst., Utah-Idaho Sugar Co., Belle Fourche, S. Dak., respectively.

[3] Figures in parentheses refer to literature cited.

**Experimental Procedure**

The following trials were conducted on the Pierre clay at Newell, South Dakota, and on the Orman clay at Arpan, South Dekota:

**Trial 1.** VAMA was incorporated with Pierre clay soil at the rates and depths indicated in Table 1 in May of 1952. All rates of the additive occurred with and without starter phosphate consisting of 40 pounds of $P_2O_5$ per acre applied as triple superphosphate in bands 4 inches wide and 3 inches deep at the location of the sugar beet row. Application was accomplished by broadcasting the phosphate and/or VAMA on the soil surface and incorporated by the use of a Merry tiller. Each plot was 30 feet long and 4 beet rows wide. The treatments were completely randomized in each of the three replications.

Eleven decorticated sugar beet seeds were planted per foot of row by the use of an experimental belt type fertilizer applicator and appropriate furrow openers on May 13. The number of seedlings which had emerged were counted on May 21, 24 and 28 for two 100-inch sections of row in each plot.

Composited disturbed soil samples were collected for water stable aggregate analysis in July, 1952. These were collected from the unfertilized check plots and from the unfertilized plots treated with .20 percent VAMA to a depth of 6 inches.[4]

**Trial 2.** The four additive treatments given in Table 1 were placed on plots 70 feet long and 12 beet rows wide on the Orman clay in May, 1952. The four replications of these large plots were subdivided into 6 fertilizer plots each 35 feet long and 4 rows wide. The additive and fertilizer were broadcast on the soil surface and incorporated to a depth of 4 inches by the use of a garden size rototiller and a Merry tiller. The whole area was then harrowed once to firm the seedbed. Decorticated sugar beet seed was planted at the rate of approximately 6 pounds per acre with a commercial International drill on May 15. The number of plants emerged on one 100-inch section of each of the two middle rows of each 4-row plot was counted after emergence was complete.

**Trial 3.** In the spring of 1952, the Pierre clay on one-half of a series of 18 small plots, 9 x 30 feet, was aggregated with HPAN to a depth of 14 inches. The additive was applied by removing the soil with a small crawler-type tractor equipped with a front-mounted blade. As the soil was replaced, a little at a time, the additive was incorporated by the use of a small rototiller. Moisture treatments were superimposed and corn produced on the plots in 1952. The late fall irrigations and precipitation made the soil moisture content uniformly high for all plots as winter began.

In May of 1953 a seedbed was prepared by rototilling and harrowing. Decorticated sugar beet seed at the rate of approximately 6 pounds per acre was planted with a commercial type drill on May 5. The number of seedlings emerged was determined by counting six 100-inch sections of row in

[4] Aggregate analysis in all trials was determined at the Soil and Water Conservation Research Branch Laboratory at Mandan, North Dakota.

each plot on each of three dates. The soil temperature was determined on various dates by inserting a thermometer into the soil to the desired depth and taking the reading after a lapse of about one minute. Three such readings were made for each plot on each date.

Composite disturbed samples of soil were collected in July of 1952 for water stable aggregate analysis from the top six inches of soil on both the additive-treated and untreated plots.

Natural weather conditions were depended upon to produce a crust in the first three trials and a crust was produced artificially in the two trials which follow.

**Trials 4 and 5.** These two trials were conducted on the Pierre clay in the fall of 1953. Decorticated sugar beet seed was planted with a hand-operated garden drill on September 7 and 27 for Trials 4, and 5, respectively. VAMA, IBMA and CMC at 0 to 66 pounds per acre, treated area, were applied as a .3 percent water solution sprayed in a band 4 inches wide on the soil surface above each planted row. The rates were obtained by maintaining a constant pressure in the portable hand sprayer and varying the length of time of application. There were four replications of the treatments on the 15-foot single row plots.

One day or more after the application of the additive, water from a garden hose was sprinkled on each row to insure the formation of a crust.

**Table 1.—The Number of Plants Emerged Per 100 Inches of Row and the Percent of Water Stable Aggregates in the Trials in Which the Additives Were Incorporated With the Soil.**

| Additive | Rate for treated area: Pounds per acre | % of soil weight | Depth of incorporation (inches) | Plants per 100 inches | | | | Percent aggregation >2.0 mm | Percent aggregation >.2 mm |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Date | | | | | |
| **Trial 1. Pierre clay—1952[1]** | | | | 5/21 | 5/24 | 5/28 | 6/4 | | |
| None | 0 | — | — | 11 | 54 | 60 | | 3.9 | 51.3 |
| VAMA | 250[2] | .025 | 3 | 9 | 59 | 63 | | | |
| VAMA | 500[2] | .05 | 3 | 21 | 55 | 61 | | | |
| VAMA | 250[2] | .05 | 1½ | 11 | 63 | 66 | | | |
| VAMA | 1000[2] | .10 | 3 | 12 | 65 | 64 | | | |
| VAMA | 2000[2] | .20 | 3 | 15 | 61 | 65 | | | |
| VAMA | 4000 | .20 | 6 | 10 | 60 | 58 | | 20.0 | 78.5 |
| L.S.D. at .05 for any date | | | | NS | NS | NS | | | |
| **Trial 2. Orman clay—1952[1]** | | | | | | | | | |
| None | 0 | — | — | | | | 32 | | |
| VAMA | 330 | .05 | 4 | | | | 34 | | |
| HPAN | 330 | .05 | 4 | | | | 31 | | |
| HPAN | 1320 | .20 | 4 | | | | 38 | | |
| L.S.D. at .05 | | | | | | | 4 | | |
| **Trial 3. Pierre clay—1953** | | | | | | | | | |
| None | 0 | — | — | 9 | 22 | 30 | | 20.6 | 70.0 |
| HPAN | 4666 | .10 | 14 | 22 | 37 | 46 | | 38.8 | 93.7 |
| L.S.D. at .05 for any date | | | | 7 | 7 | 7 | | | |

[1] The emergence reported is the average for the additive treatment receiving the various fertilizer treatments.

[2] Applied in bands 4 inches wide in the sugar beet rows 22 inches apart; thus, actual rate is 4/22 of the amount given.

The end of the garden hose was placed in a one-gallon can having nail holes punched in the bottom and held a few inches above the ground. The amount applied to each plot was held constant by making the length of time of application to each plot about 45 seconds. The subsoil was dry and to facilitate germination it was necessary to apply supplemental water by gently sprinkling with water. This was applied after the other treatments and was gentle enough that a crust was not produced on the untreated soil between the rows.

The number of plants emerged per 100 inches of row was determined on three dates for both Trial 4 and 5.

## Results and Discussion

The results of stand counts are given in Table 1. The data have been analyzed statistically and in no instance was an interaction between date x treatment found.

**Trial 1.** The number of plants emerged in Trial 1 was more than 60 percent of the total number of seeds planted. Such a proportion is a very good emergence. Neither the additive treatment nor the starter phosphate had any effect on emergence. There was no crusting problem and the soil moisture conditions were good. The results of the laboratory analysis, given in Table 1, indicate that the percentage of water-stable aggregates was increased by treatment with additive. This effect was visibly apparent in the field.

**Trial 2.** In Trial 2 the number of plants emerged on the soil treated with 1,320 pounds per acre of HPAN was 10 to 20 percent greater than that of the other treatments. Although not statistically significant, there was a tendency for the emergence on the plots treated with 330 pounds per acre of VAMA to be slightly greater than the emergence for either the same rate of HPAN or for the untreated check.

**Trial 3.** A very definite increase in the emergence of plants and the aggregation of the soil was attributed to the treatment with HPAN in Trial 3. The total number of plants emerged per 100 inches of row was

**Figure 1. Because of the difference in the soil temperature the snow melted from the plots having normal soil before it melted on those plots with additive-treated soil.**

30 on the untreated soil in comparison to 46 on the treated soil. In as much as there was very little crusting of the soil surface it is likely that other factors must be considered to explain this large difference. The additive-treated soil appeared to be more friable and less hard than the untreated soil. The degree of hardness of the soil below the surface is no doubt just as important as the surface condition termed "crusting," except that crusting is a more extreme and easily observed condition. It was also observed that during the period of germination and emergence the temperature of the additive-treated soil was higher than that of the normal soil.

**Table 2.—A Comparison of the Temperature of the Additive-treated Soil and Normal Soil in Trial 3.**

| Date | Mean air temperature (Degrees C.) | Soil temperature, degrees Centigrade | | | |
|---|---|---|---|---|---|
| | | ¾-inch depth | | 2½-inch depth | |
| | | Normal soil | HPAN treated | Normal soil | HPAN treated |
| April 8 | —0.6 | 7.3 | 6.5 | ..... | ..... |
| April 13 | 3.9 | 12.7 | 13.4 | 10.0 | 10.0 |
| April 20 | 12.2 | 14.2 | 15.5 | 13.0 | 13.8 |
| May 19 | 13.9 | 24.9 | 25.5 | 23.2 | 23.7 |
| May 27 | 22.2 | 23.1 | 23.9 | 22.1 | 22.6 |

L.S.D. at .05 between treatments on any date: ¾ inch depth .7. 2½ inch depth NE.

Attention was first focused on the difference in soil temperature by the observance of a checkerboard pattern produced by the location of the melting snow on the morning of April 8, 1955, as shown in Figure 1. The rate at which the thin layer of snow melted was slower and the soil temperature lower on the additive-treated plots. In contrast, the soil temperature data in Table 2 for the remainder of the spring season indicates that the additive-treated soil was "warmed up" more readily by the warm spring air. This factor may have been of importance in as much as the higher temperatures were favorable to the germination and growth of seedlings.

**Figure 2. Typical appearance of a 4-inch band of soil treated with soil additive (VAMA at 12 pounds per acre). Left. Contrast with untreated check. Right. Note that the string crosses the band about 3 inches to the left of the division between treated and untreated area.**

**Trials 4 and 5.** There was no difference in the emergence attributed to additive treatment in Trials 4 or 5. It was possible to see the effect of the additive treatment on a thin layer of soil surface where the spray applications were made (Figure 2). Nevertheless, the soil just beneath the surface was hard and cracked.

## Conclusions

The results of these studies indicate that the soil additives will aggregate and improve the physical condition of the soil. The emergence of sugar beet seedlings was increased, under the conditions of these trials, however, only when the additive was applied at rates of several hundred pounds per acre and incorporated to a depth of four or more inches in the soil. It is possible that emergence would have been increased with the shallower incorporations of additive, if crusting conditions had prevailed during the time such treatments were being tried.

An increase of emergence was not obtained in the trials where low rate spray applications of dilute solutions of the additive were made. Nevertheless there may be some value for such a procedure as in these trials rather a severe "crust" or "caking" was produced. These trials do indicate that we cannot expect surface applications of soil additives to control thick crusting or caking but they may be of value in controlling a shallow surface crust. The economy and ease of applying the additives as a dilute spray suggests that more trials of this type should be conducted under commercial field conditions. Low rates of application per acre can probably be more satisfactorily obtained by reducing the width of the treated area rather than reducing the rate on the area treated.

## Summary

The value of chemical additives to increase the emergence of sugar beet seedlings was studied in five field plot trials on the clay soils of western South Dakota.

Application was made by broadcasting the additives on the soil surface and incorporating them to various depths in three of the trials. Natural weather conditions were depended upon to produce a crust on the soil surface.

Additives were also applied as dilute water solutions, .3 percent, sprayed on the soil surface in two of the trials. A rather severe crust was produced by applying water with a garden hose.

An increase in emergence attributed to the additive treatment was obtained in two of the three trials in which natural weather conditions were depended upon to produce a crust. Although no increase in emergence was obtained by the relatively economical surface spray method of application, this method may be satisfactory with less severe crusting conditions. The effect of the additive on the soil was visibly apparent in all of the trials.

## Literature Cited

(1) Anonymous
1953. Soil conditioners. What have we learned since '51? What's New in Crops and Soils, 6 (1):10-11.

(2) BAIRD, BRUCE L.
1952. The response of sugar beets to fertilizer in western South Dakota. Proc. Amer. Soc. Sugar Beet Tech., 189-195.

(3) MARTIN, W. P.
1953. Status report on soil conditioning chemicals. I. Soil Sci. Soc. of Amer. Proc., 17:1-9.

(4) SHERWOOD, L. V., and ENGIBOUS, J. C.
1953. Status report on soil conditioning chemicals. II. Soil Sci. Soc. of Amer. Proc., 17:9-16.

(5) TOLMAN, BION
1946. Response to nitrogen and phosphate fertilizers in the intermountain area. Proc. Amer. Soc. Sugar Beet Tech., 45-53.

(6) TOLMAN, BION, JOHNSON, RONALD, and BIGLER, A. J.
1948. Soil fertility studies in the Mountain States. Proc. Amer. Soc. Sugar Beet Tech., 397-406.

# Influence of Krilium Soil Conditioner on Sugar Content of Beets

C. H. Smith[1]

## Introduction

Investigations reported in this paper with Krilium soil conditioner were initiated in connection with sugar beet varietal studies. Two different types of injury to the beet root had been observed in the vicinity of Salt Lake City. These injuries were thought to be associated with inadequate soil aeration. Certain inbred lines of beets were much more susceptible to the injury than others. It was assumed that a soil conditioner might provide better aeration.

Therefore, in 1952 five inbred lines of beets were included in a field test which consisted of three Krilium-treated blocks and three controls. Varieties appeared in two-row plots 39 feet long. Each treatment block contained five of these variety plots. It turned out that no significant differences were observed for the amount of root injury on the treated and control blocks. However, there was a remarkable difference in soil structure and when the beets were analyzed those from the Krilium-treated blocks showed a higher sugar percentage, also a better purity and a lower sodium content. In 1953 the test was repeated with one additional replication, but highly vigorous varieties and $F_1$ hybrid beets were grown on the treated and control plots instead of inbred lines.

The soil type on the experimental field for both years was Welby fine sandy loam with 18 to 20 percent clay, having a lime zone in the subsoil and of about medium alkalinity. A crop rotation of grain and onions, along with a good fertilizer program, maintained the soil at a high fertility level. A heavy application of chicken litter (15 spreader loads per acre) and commercial fertilizer (100 pounds treble superphosphate and 100 pounds of ammonium sulphate per acre) was worked into the soil during seed bed preparation.

## Experimental Results, 1952 Test

Krilium No. 6, produced by the Monsanto Chemical Company, was applied April 23, 13 days after planting, just as seedlings were beginning to appear. The application rate was 2,000 pounds per acre applied with a hand-drawn grass seeder. A tractor-drawn harrow moving crosswise of the rows worked the Krilium into the top one inch of soil. Shortly after application treated plots became crusted. In the early morning hours the soil in treated plots was gummy and sticky but hardened during the day. Crusting continued to be a problem until several cultivations and irrigations aided in more thoroughly mixing the Krilium with a larger quantity of soil. By midsummer, soil on treated plots did not become crusted or packed between irrigations and was much more friable than soil in control plots. Krilium brought about beneficial changes in the physical structure of the soil. Treated soil did not dry out as rapidly and maintained better porosity and more rapid water penetration than did soil on control plots.

---

[1] Agronomist, Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture.

Although emergence stands were not as uniform and heavy as desired, the stands on treated plots were as uniform as those on control plots. The late application of the Krilium caused soil crusting and required special treatment until the beet seedlings emerged. Subsequent rate of growth, color of foliage, vigor of plants, or rate of crop maturity were not noticeably different on treated and control plots.

In the final analysis of results, yield was not affected within varieties. The main differences were in sucrose percentage, purity and sodium content. A small but consistent increase was noted in sucrose percentage. An average overall difference of 0.65 percent sucrose was obtained in favor of the Krilium treatment (see Table 1). Likewise the overall difference of 1.57 percent purity was in favor of Krilium treatment. A corresponding decrease in sodium content was observed in favor of Krilium treatment. The small overall difference in amino nitrogen percentage was not significant.

**Table 1.—Results from Field Test, 1952**

| Replication | Treatment | Sucrose | Sodium | Amino Nitrogen | Purity | Beets Per Acre |
|---|---|---|---|---|---|---|
| | | Percent | p.p.m. | Percent | Percent | Tons |
| | Krilium | 13.98 | 597.0 | 0.470 | 80.92 | 26.68 |
| 1 | Control | 13.37 | 700.0 | 0.628 | 78.94 | 27.28 |
| | Difference | +0.61 | —103.0 | —0.158 | +1.98 | —0.60 |
| | Krilium | 14.73 | 421.8 | 0.640 | 81.04 | 27.00 |
| 2 | Control | 14.14 | 612.8 | 0.618 | 80.86 | 29.94 |
| | Difference | +0.59 | —191.0 | +0.022 | +0.18 | —2.94 |
| | Krilium | 14.05 | 559.2 | 0.584 | 80.48 | 28.10 |
| 3 | Control | 13.29 | 659.2 | 0.658 | 77.92 | 27.12 |
| | Difference | +0.76 | —100.0 | —0.074 | +2.56 | +0.98 |
| | Krilium | 14.25 | 526.0 | 0.565 | 80.81 | 27.26 |
| Average | Control | 13.60 | 657.3 | 0.635 | 79.24 | 28.11 |
| | Difference | +0.65 | —131.0 | —0.07 | +1.57 | —0.85 |
| Standard Error | | 0.05 | 29.88 | 0.04 | 0.72 | 0.86 |
| t Value (S.E. ÷ Diff.) | | 12.08[2] | 4.38[1] | 1.71 | 2.19 | 0.99 |

[1] t = 4.30 for 5 percent level of significance.
[2] t = 9.92 for 1 percent level of significance.

Krilium treatment did not affect the amount of root rot or internal breakdown, which was the primary purpose of the test.

## 1953 Test

In 1953 a replicated test of five varieties of sugar beets, chosen because of their high or low sodium or sugar relationships under normal conditions, were superimposed upon four Krilium-treated and four control blocks.

Krilium No. 6 was applied at the rate of 700 pounds per acre by a hand-drawn grass seeder and raked into the surface inch and one-half of soil with hand rakes just prior to drilling the seed March 24, a rather early planting date for this area.

After light spring rains the Krilium treatment sealed the soil surface. The crust which formed became hard when dry and had to be broken prior

to seedling emergence. Temperatures were cool and frequent storms, both rain and snow, maintained good soil moisture. Seedling emergence in general was slowed up considerably due to prolonged low temperatures. However, seedlings appeared first on Krilium-treated plots. This was believed due to the darkened color of the soil and better soil aeration caused by better aggregation of soil particles on treated plots. Seedling growth was faster on Krilium-treated plots before thinning, but after thinning growth became more uniform.

Excellent stands of beets were obtained on both treated and control plots. No differences were observed in growth, color of plants or rate of maturity. The physical structure of the soil in treated plots was definitely improved over control plots. Although the soil was rather wet at harvest due to a late irrigation and rains just prior to harvest, soil on treated plots was friable compared to the compact balling effect of soil on control plots.

Harvest data indicated very small differences between treated and control plots for tons of beets, sodium, nitrogen and potassium control (Table 2). No difference was observed in average sucrose content from treated and control plots.

**Table 2.—Results from Field Test, 1953.**

| Replication | Treatment | Sucrose | Sodium | Amino Nitrogen | Purity | Potassium | Beets Per Acre |
|---|---|---|---|---|---|---|---|
| | | Percent | p.p.m. | Percent | Percent | p.p.m. | Tons |
| 1 | Krilium | 15.10 | 559.0 | 0.346 | 87.46 | 3,528.4 | 44.30 |
| | Control | 14.38 | 615.4 | 0.374 | 85.82 | 3,741.2 | 43.38 |
| | Difference | +0.72 | —56.4 | —0.028 | +1.64 | —212.8 | +0.92 |
| 2 | Krilium | 16.72 | 235.9 | 0.306 | 89.16 | 3,353.6 | 42.00 |
| | Control | 16.94 | 277.8 | 0.308 | 89.26 | 3,355.8 | 42.02 |
| | Difference | —0.22 | —41.9 | —0.002 | —0.10 | —2.2 | —0.02 |
| 3 | Krilium | 16.56 | 285.4 | 0.376 | 88.44 | 3,589.2 | 40.82 |
| | Control | 16.96 | 267.2 | 0.292 | 89.38 | 3,417.8 | 41.28 |
| | Difference | —0.40 | +18.2 | +0.084 | —0.94 | +171.4 | —0.46 |
| 4 | Krilium | 16.58 | 315.2 | 0.248 | 90.08 | 3,130.8 | 40.94 |
| | Control | 16.68 | 257.4 | 0.326 | 89.44 | 3,414.4 | 40.84 |
| | Difference | —0.10 | +57.8 | —0.078 | +0.64 | —283.6 | +0.10 |
| Average | Krilium | 16.24 | 348.85 | 0.319 | 88.78 | 3,400.50 | 42.01 |
| | Control | 16.24 | 354.45 | 0.325 | 88.47 | 3,482.35 | 41.88 |
| | Diffrence | 0.0 | —5.6 | —0.006 | +0.31 | —81.85 | +0.13 |
| Standard Error | | 0.35 | 33.66 | 0.0443 | 0.62 | 109.84 | 0.35 |
| t value (S.E. ÷ Diff.) | | 0.35 | 1.66[1] | 0.0014 | 0.50 | 0.75 | 0.38 |

[1] t = 3.18 for 5 percent level of significance.

## Summary and Conclusions

In 1952 a heavy application (2,000 pounds per acre) of Krilium soil conditioner improved soil structure but failed to alleviate two special types of injury prevalent to beet roots on Welby fine sandy loam soil near Salt Lake City. However, the sucrose percentage was increased and sodium content in the beets was reduced by the treatment. This test was conducted

with inbred lines of sugar beets. The experiment was repeated in 1953 with a reduced quantity of Krilium (700 pounds per acre) and with vigorous hybrid sugar beets instead of inbreds. Seedling emergence and early seedling growth were improved by the Krilium treatment. Soil structure was greatly improved. There was a slight but statistically insignificant reduction in sodium and potassium content. There was no increase in sucrose in beets from Krilium-treated plots. The final results, therefore, are not fully conclusive. The increase in sucrose percentage by the Krilium treatment in the 1952 test looked very encouragaing.

The reasons for the different results obtained in 1953 are not evident unless explained by the smaller quantity of Krilium used or by the change from the use of inbred lines to vigorous hybrid sugar beets.

# Problems Connected with High Beet Populations

L. J. Holmes and Curzon Kay[1]

**Are we leaving too many beets per foot of row?** This is the main topic of discussion at Clarksburg this season. Briefly, let us go into some of the reasons for, and the results of, high population in the beet fields.

The reasons for high populations are varied. We all know that a definite relation exists between soil fertility, adequate moisture, growing season, etc., and the population which can be maintained. A few years past when both the thinning and harvesting were done by hand we used to shoot for a 100 percent stand which to us meant 100 beets per 100 feet of 20 inch row. In the past few years, however, conditions have changed and now our harvest is almost 100 percent mechanical and spring work is rapidly moving in that direction. With these changes have come a change in our population trend.

Here at Clarksburg, on ground which is highly fertile, we found that with mechanical harvesters if our beets became too large and grew out of the ground we lost a considerable amount of our tonnage due to breakage of these large beets. In order to overcome this our growers for the past four or five years have been increasing their field population to the point where an average population has been ranging from 120 to 140 beets per 100 feet of row. This seemed to work very nicely. Our beets were more uniform in size and our tonnage continued high. However, with increased drives for mechanical thinning which have been carried out the last few years a great deal of information has been published and distributed to farmers stating that doubles do not lower yields and that fields with increased population have produced as much or more than fields with lighter population.

It is not the objective of this paper to question or argue with the many authors on this subject, but we would like to call attention to the following points which we think have been overlooked by many, and may have misled some of our growers.

**First,** it must be remembered that articles written by fieldmen and farmers which brag on increased tonnages on fields with heavy population are usually based on one year's experience and many of the fields have no check for comparison. Furthermore climatic and other conditions play a large part in production from year to year, and many of these production reports are based on only one year's results.

**Second,** it has been noted in some of the published research work on which population studies have been made that all beets were weighed which had a diameter of 1 inch or over. We feel that many of the beets which have been used in the final results are unmarketable beets. A large portion of these, if picked up by the harvester, will fall out through the potato chains on the harvesters and a great many more will be removed by the Rienks screen at the dump.

---

[1] Manager and Agricultural Superintendent, respectively, American Crystal Sugar Company, Clarksburg, California.

**Third,** we have several growers who have told us that it is the industry's fault that they have so many triples and clumps of beets in their field. They reason this way—"We had lots of doubles when we insisted on thinning to singles, but now that we don't worry much about doubles we get a whole field full of triples and clumps."

We will go along with the statement that doubles do not hurt, but when our growers begin to get lax on their field supervision, and do not insist on thinning to singles, labor immediately begins to leave triples or clumps.

Because of the tremendous population increase which we have experienced in the past year in our fields, we feel that it is high time to call attention to some of the detrimental effects of overpopulation. We want to stress emphatically at this point that we are not arguing for or against mechanical thinning and our sampling this year showed that many of the hand-thinned fields had as heavy a population as those fields handled by mechanical means.

Let us consider now some of the detrimental effects of over-population in our beet fields.

**First,** the effect on tonnage: Due to the increased number of beets per foot of row we changed our field sampling method for 1953. In taking a preharvest sample, each fieldman, using a measuring stick of 5 feet, sampled all the marketable beets in five feet of row. The fieldman's judgment was relied upon in determining marketable beets but for a general rule of thumb any beet under 1½ inches in diameter was discarded. Seventy-eight samples were taken on our early fields between the dates of June 16 to June 29. All of the beets were counted and the unmarketable beets noted. The average of these samples indicated a population of 158 marketable beets per 100 feet of row. In addition, there were more than two unmarketable beets per sample which would make more than 40 unmarketable beets per 100 feet. This would make the total visible population at harvest time in excess of 198 beets per 100 feet of row. We say visible population because it was shown this year at Clarksburg in a plot where a total population of 471 beets were left at thinning time, that 25 of these had disappeared by harvest time. The total stand counts at thinning time and the marketable beets which were harvested are shown in Table 1.

It seems obvious to us regardless of the final tonnage of clean beets produced that the 40 or more unmarketable beets per 100 feet of row which survived to harvest competed with the marketable beets and had a tendency

**Table 1.—Population Studies—100 Feet of Row 1953. A. E. Greene, Clarksburg.**

| | No. Beets After Thinning | No. Beets at Harvest | Marketable Beets | | Unmarketable Beets | | Sclerotium Beets (Not Weighted) | % Sugar | Tons Per Acre | | Lbs. Sugar Per Acre |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | No. | Wt.(Lbs.) | No. | Wt.(Lbs.) | | | Marketable | Unmarketable | |
| Dixie | 471 | 466 | 197 | 155.58 | 196 | 26.31 | 53 | 15.7 | 20.2 | 3.4 | 6,388 |
| Hand | 182 | 176 | 137 | 185.77 | 37 | 6.00 | 2 | 15.3 | 24.2 | 0.8 | 7,430 |

to lower the tonnage. Any other plant competing against the beets for soil nutrient would be called a weed. The unmarketable beets have the same effect.

**Second,** let us consider harvest problems caused by overpopulation. The average tare for the first 30 days of harvest in 1952 was 4.0 percent. The average tare for the first 30 days of 1953 was 6.6 percent. This is a comparison of the beets received over the same factory dump, from the growers in the same factory area, and in both cases the beets were approximately 98 percent mechanically harvested. This means that due to the increased number of small beets which are poorly topped plus the number of unmarketable beets which are screened through the Molnau screen, the grower is hauling 2.6 percent more material for which he is not receiving profit and the company is handling 2.6 percent more trash which has a tendency to slow down factory operations. Table 2 is a comparison of the amount of unmarketable beets which went through the Molnau screen at Clarksburg showing the variation between growers with high population as compared to those with a lower population.

**Table 2.—Comparison of the Amounts of Unmarketable Beets in the Screenings from Average 6 Ton Loads at Clarksburg—September 30, 1953.**

| | Population Per 100' of Row at Harvest Time | Total Wt. of Screening | Wt. of Small Beets in Screenings | Number of Small Beets in Screenings |
|---|---|---|---|---|
| | | Lbs. | Lbs. | |
| Hand Thinning | 110 | 260 | 3.31 | 55 |
| Hand Thinning | 158 | 560 | 93.13 | 940 |
| Cross-Blocked | 165 | 570 | 100.57 | 977 |
| Dixie Thinner | 173 | 1,200 | 145.76 | 1,293 |

**Third,** there is the problem caused by increased susceptibility to certain diseases in heavy populations. This year at Clarksburg we have experienced one of the worst sclerotium root rot outbreaks since 1945. It is our opinion that the tonnages at Clarksburg will, for the factory district, be lowered at least a ton per acre due to *Sclerotium rolfsii.* We all know that there are many factors influencing the degree and severity of this disease from year to year. However, Dr. L. D. Leach, plant pathologist at the University of California at Davis, has this to say in one of his articles on this subject. "It is well known that when one sugar beet becomes infected by the southern root rot fungus, the disease quickly spreads to other plants left in the same block. More important, however, is the fact that doubles or multiples are about three times as apt to become infected as single beets in the same field. This conclusion is based on observations of 56,000 beets in several commercial fields in Yolo, Sutter, and Solano counties." (1)[2]

Dr. Leach concludes his article with the following statement: "It is, therefore, suggested that in fields known to be infected with *Sclerotium rolfsii* care should be exercised in thinning to obtain a high percentage of single beets."

[2] Numbers in parentheses refer to literature cited.

In conclusion, it is our opinion that overpopulation has the following detrimental effects. Tonnage is reduced due to unmarketable beets competing with marketable beets. The quality of harvest is lowered due to small and poorly topped beets. Susceptibility to disease is increased.

We believe uniform spacing is more important in the final analysis than total population. We feel that such glib remarks as "doubles do not hurt yields," and others, which are often made to growers without the necessary elaboration on all aspects of the problem, can do considerable harm.

## Literature Cited

(1) L. D. LEACH
1942. Multiple beets more susceptible to rot than singles. Spreckels Sugar Beet Bulletin.

# Estimate of Space Occupied Proposed as a Measure of Sugar Beet Stands

G. W. Deming[1]

When sugar beets were hand thinned predominantly single-plant hills were left in the thinned stands. The basic spacings between those single-plant hills might vary from grower to grower and different workers seldom attained exactly the same spacing. However, the spacing of the thinned stand usually approximated that desired by the grower and was reasonably uniform for any given field. Under these conditions any statement of the stand which included the basic spacing and the number of plants in a given length of row gave a reasonably accurate picture of the plant population of that field.

The increasing use of machines for thinning the sugar beet crop has changed our concept of an acceptable thinned stand of sugar beets. Basic spacings are much less than with hand thinning and the individual hills may contain one, two, or several plants. Good yields have been obtained by growers from a rather wide range of plant populations. It is probable that very good to near maximum yields may result when plant populations are only sufficiently reduced to permit most plants to make relatively small, but marketable beets. It is also probable that equally good yields may occur from stands with many fewer plants so distributed that most of the space and available plant food will be used to produce, in that case, relatively large beets.

When 2-plant and multiple-plant hills occur in the stand in appreciable numbers, as is usually the case in machine-thinned stands of sugar beets, it appears obvious that the number of plants in a given length of row is an inadequate measure of the stand. The distance between hills in a machine-thinned stand may, and usually does, vary from very little to considerable, depending on how often a beet plant-containing hill is left in each of the small blocks between the successive strokes of the cutting knives of the machine. Thus, the row space that could be completely used by a single hill may contain more than one hill. The number of hills in a given row length of such a stand is, probably, a better measure of the population than the number of plants, but still falls short of being an accurate measure of the stand.

It is the purpose of this paper to propose an estimate of the space actually occupied by the sugar beet plants present in a machine-thinned stand as a measure of the plant populations of such stands.

Before such an estimate can be made it is necessary to make some assumptions on the use of space by sugar beet plants. Tolman, Johnson and Bigler (4)[2] and Deming (2) have reported experiments which indicate

---

[1] Agronomist, Field Crops Research Branch, Agricultural Research Service, United States Department of Agriculture. Agronomic research with sugar beets at Fort Collins, Colo., is in cooperation with the Agronomy Section of the Colorado Agricultural Experiment Station. Colorado Agricultural Experiment Station Scientific Paper No. 439.

[2] Numbers in parentheses refer to literature cited.

that the effect of row width on yield of sugar beets was essentially independent of the number of plants in the row. Therefore, the spacing between rows may be safely ignored and the estimate of space occupied can be based on the distribution of sugar beet plants within the row. Coons (1) has reviewed European and American literature reporting the effect of space relationships on the sugar beet crop.

There is general agreement that when space is fully occupied it makes little difference how many plants are present, provided each of them has sufficient room to produce a beet of marketable size. In general, the crops from thick stands have slightly higher sucrose content than those from thin stands. This tends to compensate for small losses from beets of unmarketable size when the upper limits of plant populations have not been seriously exceeded. Therefore, in arriving at an estimate of space occupied we may assume that the only limit on the total number of plants in a given length of row is that most of them must have sufficient space to develop a root of marketable size. If more than this number of plants is present in an appreciable portion of the field it is only evidence of a poor job of thinning. Such a condition is of infrequent occurrence and as growers gain experience in machine thinning it will be even less likely to occur.

It remains to define the maximum space between hills in the row at which the beet plants will presumably fully use the plant food, moisture and room at that location. American growers of sugar beets more or less agree that 12 inches between hills in the row is an optimum spacing. There is less general agreement on a permissible maximum spacing. Tolman (5) reported that under some conditions yield could be maintained as spacing in the row was increased to 15 inches between hills and that "Yields begin to decline as spacing within the row is increased to 20 inches." Deming (3), reporting on experiments at Fort Collins, Colorado, states that when approximately full stands were maintained the differences in yield from 8-, 12- and 16-inch spacings in the row were negligible. Spacings used by sugar beet growers in the Colorado-Nebraska-Wyoming area have varied appreciably and many excellent yields have been harvested from stands with row spacing in excess of the assumed optimum of 12 inches.

On the basis of this evidence it is tentatively assumed that sugar beet plants will fully occupy the space within the row when the maximum space between hills approximates 16 inches. However, as a matter of convenience, in the actual measurement of spaces undertaken in 1953 and reported in Table 1 no "Lost space" was recorded unless the space between hills was 18 inches or more. Thus, all spaces between hills up to and including 17.5 inches were ignored in collecting the data. All spaces of 18 inches or more were noted, 16 inches subtracted and the remainder recorded as unoccupied space. The total of inches of unoccupied space in each plot was subtracted from the total inches of row for the plot to obtain the total inches of row occupied by beet plants and from this value percent of occupied space was calculated.

After thinning the experimental sugar beet plots on the Agronomy Farm at Fort Collins, Colorado, in 1953, the spaces between hills of the inside (for harvest) rows of two variety tests were measured and unoccupied

space for all plots recorded. Counts of hills in the same plots were also made. From these records percentage of space occupied and hills per 100 feet of row were calculated as estimates of the thinned stands. These estimates of stand for the agronomic evaluation test of leaf spot and black root-resistant varieties were statistically analyzed by the analysis of variance for a Latin square. A summary of these data is given in Table 1.

**Table 1.—Thinned Stands of Sugar Beets; Agronomic Evaluation Variety Test, Fort Collins, Colo., 1953. Stands Recorded as: (1) Hills Per 100 Feet of Row, (2) Percent of Row Length Occupied by Sugar Beet Plants. Data Given as 8-Plot Averages.**

| Column, row or variety number | Stand as hills for | | | Stand as occupied space for | | |
|---|---|---|---|---|---|---|
| | Columns | Rows | Varieties | Columns | Rows | Varieties |
| | (hills per 100 feet of row) | | | (percent space occupied) | | |
| 1. | 102.4 | 99.5 | 100.9 | 94.5 | 93.5 | 93.5 |
| 2. | 103.3 | 108.0 | 106.8 | 94.7 | 94.2 | 95.4 |
| 3. | 103.9 | 102.1 | 102.0 | 95.0 | 93.7 | 93.5 |
| 4. | 98.3 | 100.7 | 102.1 | 93.3 | 92.5 | 94.1 |
| 5. | 104.6 | 100.3 | 109.1 | 93.9 | 95.2 | 95.8 |
| 6. | 105.9 | 106.4 | 102.0 | 94.4 | 95.4 | 94.1 |
| 7. | 103.5 | 107.0 | 102.5 | 94.6 | 94.8 | 93.5 |
| 8. | 109.3 | 107.4 | 105.9 | 94.9 | 95.9 | 95.3 |
| Mean | 103.9 | 103.9 | 103.9 | 94.4 | 94.4 | 94.4 |
| F. value[1] | 6.14** | 8.25** | 5.56* | [2] | 3.30** | 2.45* |
| 2 x the S.E. of a Diff. | 3.5 | 3.5 | 3.5 | 1.8 | 1.8 | 1.8 |
| S.E. of mean in % of the gen. mean | 1.20 | 1.20 | 1.20 | 0.66 | 0.66 | 0.66 |

[1] Designated F. value at 5% level with **, and 1% level with *.
[2] Ve exceeds Vc.

The plots in this 8 x 8 Latin square were 30 feet in length and 8 rows in width. The initial stands were good and fairly uniform. A moderately weedy condition extended across the field rows of the test at about "Row 4" of the summary table. The test was thinned by four laborers who worked one row at a time in pairs or singly on various portions of the experiment. No record was made of the rows worked by different individuals, though it was noted at the time that the spacings being used by the laborers varied from about 8-10 inches by two teenagers to approximately 11 inches by the two experienced older workers. The subsequent count of hills showed that full stands varied from about 31-33 hills to well over 40 hills per 30-foot plot row. It is known that the two teenagers worked more of the plots represented in "Columns 6-8" of the table than they did of the balance of the experiment.

When hills per 100 feet of row were used as the estimate of stands in this test the F value for columns, rows and varieties each exceed the one percent point for probable significance. Conversion of the estimates of stand to space occupied materially reduced the variability in this test. In the case of columns Ve exceeded Vc and the F values for rows and varieties, while still exceeding the one percent point and the five percent point, respectively, are less than half as great as when hills were used as the measure of stand.

Since stands in this test were relatively good, as evidenced by the variety means and the general mean, some further comment may be warranted. As

the number of hills in a given length of row would be influenced by the basic spacings used by the different laborers the differences, if any, would be found in the column means of the table. The F value for columns indicates that highly significant differences for hills did exist. However, when space occupied was used as the estimate of stands no significant differences between column means were found.

The estimate of space occupied would probably be of the most value as a measure of stands obtained by machine thinning. Usually an appreciable portion of the hills in machine-thinned sugar beets contains more than one plant and there is less uniformity of the space between hills than with hand-thinned stands. Both of these factors tend to make estimates of stand based on counts of plants or hills more or less unrealistic. Unfortunately data on the stand of a machine-thinned field of sugar beets by all three methods of estimating stand were not obtained. It seemed possible that some of the populations studies conducted at Fort Collins in previous years had some of the characteristics of a machine-thinned stand. It was found that stands for all plots of the populations study conducted in 1949 had been recorded as the condition of each hill, i.e., 1, 2- or 3-plant hill or blank hill, in sequence for each row of the plots. Since 8- and 12-inch spacings and various combinations of blanks, 1-, 2- and 3-plant hills were used in this experiment part of the variables to be expected in machine-thinned stands were probably represented in these plots. However, 8 inches was the minimum spacing of any treatment in this experiment and thus there were none of the very close spaced hills often present in machine-thinned stands.

Obviously it was now impossible to measure the spaces which were between the hills of these plots and it was, therefore, necessary to assume that the planned spacings, 8- or 12-inch respectively, had been attained. Using this assumption and the definition of unused space previously given the total hills, total plants and occupied space for each plot were calculated. This study was of eight treatments grown in six randomized blocks. The plots were 60 feet in length and 8 rows in width. All data are from the six inside rows of each plot. Since, by definition, all space is occupied unless the distance between hills exceeds 16 inches single skips in 8-inch stands were ignored; two adjacent skips charged with 8 inches of unused space, etc.

In the case of 12-inch spacings single skips were charged with 8 inches of unused space, two adjacent skips charged with 20 inches, etc. Data for stands as hills, plants or occupied space for this experiment are presented in Table 2. The recorded yields of roots are added in the last column of this table as of possible interest.

As Ve exceeds Vb for all three estimates of stand and the block means have been omitted as of no probable interest. Since the treatments in this test were designed to obtain large stand differences the F values for the three estimates of stand, while very great, are probably of little importance. In this case the conventional analysis of variance for a random block test gave little information on the three estimates of stand, except that the space

**Table 2.—Thinned Stands and Acre Yields of Roots, Populations Study, Fort Collins, Colo., 1949. Stands Expressed as: (1) Hills Per 100 Feet of Row, (2) Plants per 100 Feet of Row, (3) Percent of Row Length Occupied by Sugar Beet Plants. Data Given as 6-Plot Averages.**

| No. | Spacing in row | Treatments: Hills per 100 feet of row | | | | Stands; expressed as | | | Acre yield roots |
|---|---|---|---|---|---|---|---|---|---|
| | | Blank | 1-plant | 2-plant | 3-plant | Hills per 100-ft. | Plants per 100 ft. | Occupied space | |
| | (inches) | (numbers) | | | | (number) | (number) | (percent) | (tons) |
| 1. | 12 | 0 | 100 | 0 | 0 | 99.4 | 99.4 | 97.7 | 19.74 |
| 2. | 8 | 0 | 150 | 0 | 0 | 136.5 | 136.5 | 97.9 | 19.25 |
| 3. | 8 | 50 | 60 | 30 | 10 | 106.1 | 159.3 | 89.5 | 17.14 |
| 4. | 12 | 0 | 70 | 25 | 5 | 98.9 | 132.4 | 97.2 | 18.52 |
| 5. | 12 | 20 | 56 | 20 | 4 | 82.5 | 110.6 | 84.5 | 19.07 |
| 6. | 12 | 30 | 49 | 18 | 3 | 71.9 | 96.4 | 77.2 | 18.81 |
| 7. | 12 | 40 | 42 | 15 | 3 | 60.3 | 81.7 | 64.7 | 16.75 |
| 8. | 12 | 50 | 35 | 13 | 2 | 52.4 | 70.6 | 60.1 | 16.48 |
| Mean | | | | | | 88.5 | 110.9 | 83.6 | 18.22 |
| F. value (for blocks)[1] | | | | | | [2] | [2] | [2] | 8.78** |
| F. value (for treatments) | | | | | | 310.43** | 116.57** | 156.59** | 7.33** |
| 2 v the S.E. of a Difference | | | | | | 4.4 | 7.8 | 3.4 | 1.30 |
| S.E. of mean in percent of the general mean | | | | | | 1.76 | 2.50 | 1.43 | 2.53 |

[1] Designated F. value at 5% level with **

[2] Ve exceeds Vb.

occupied estimate resulted in the lowest standard error value and a lower difference for probable significance than either of the other methods of estimating stands.

However, examination of the treatment means of the stand estimates shows some interesting comparisons. Taking first the 8- and 12-inch full stands of single-plant hills, the plant or hill count estimate indicated that the 12-inch spacing fell only six-tenths of a percent short of averaging a perfect stand while the same estimate indicated that the 8-inch spacing was 9 percent short of a perfect stand. When occupied space was used as the measure of stands for these two treatments equality of the stands was indicated. Incidentally, the yields of roots were also approximately the same for both. Presumably most of the skips in the 8-inch stand were one-hill skips and did not effect the estimate of occupied space and also probably had little effect on the yield.

Another case is that of the 8-inch stand in which one-third of the hills were skips and two-fifths of the remaining hills contained 2 or 3 plants each. In this case the estimate of stand by hills indicated slightly more than a full stand by the conventional standard of 100 hills per 100 feet of row and if the estimate based on total plants is used a thick stand was indicated. However, when space occupied was used as the estimate of stand for this treatment it became obvious that it was not a full stand and that only about nine-tenths of the area was actually used to produce the crop while the other tenth was unproductive. The yield of roots was also significantly lower than the yields from full stands; an added indication that space was not fully used by the sugar beet plants.

In the case of the last four treatments given in the table, all 12-inch spacing, but with different proportions of blank hills and with 1, 2 or 3

plants in each beet-containing hill, it is obvious that the stand estimates based on total plants, while comparable among themselves, are quite misleading. The stand estimates based on total hills arealso comparable among themselves and since the basic spacing for all hills was the same they are fairly good estimates of the actual stands. However, the estimates of space occupied by the stands of these four treatments are probably just as accurate as those based on total hills and show that the actual stands were slightly better than indicated by the latter method.

## Conclusion

The proposal to use an estimate of the space occupied by the plants as a measure of thinned stands of sugar beets is advanced. Some of the assumptions that must be made to obtain such an estimate are discussed. Examples are given to indicate that the method is more accurate than estimates of stand based on either the total plants or total hills in a given length of row. This estimate of space occupied will probably be most useful as a measure of stands of machine-thinned sugar beets. More evidence is needed on this point.

## Literature Cited

(1) COONS, G. H.
1948. Space relationships as affecting yield and quality of sugar beets. Proc. Amer. Soc. Sugar Beet Tech. 1948: p. 252-268.

(2) DEMING, G. W.
1948. The effect of variations in row width and plant populations on root yields and sucrose percentage of sugar beets at Fort Collins, Colo. Proc. Amer. Soc. Sugar Beet Tech. 1948: p. 280-281.

(3) DEMING, G. W.
1942. Relative yields of reduced stands of sugar beets planted at a normal date and of replanted sugar beets. Proc. Amer. Soc. Sugar Beet Tech. 1942: p. 197-202.

(4) TOLMAN, BION; JOHNSON, RONALD; BIGLER, J. A.
1948. Row widths and sugar beet production. Proc. Amer. Soc. Sugar Beet Tech. 1948: p. 282-286.

(5) TOLMAN, BION.
1946. Population and distribution studies with sugar beets. Proc. Amer. Soc. Sugar Beet Tech. 1946: p. 177-184.

# Cultural Practices Related to Yields and Germination of Sugar Beet Seed[1]

R. A. PENDLETON[2]

A major problem in the production of sugar beet seed has been maintaining high germination quality. Much of the early production in the Pacific Northwest had germination tests of 70 to 80 percent. This has been improved in later years so that most of the crop will test above 85 percent and a considerable portion above 90 percent. However, seed from this area that will test better than 95 percent is rare. Lygus bugs and other insects can damage beet seed but control measures as worked out by Hills et al. (1)[3] eliminate most of this hazard. A partial answer has been looked for in the fertilizer and cultural program.

## Methods of Study

### A. Fertilizer Experiment.

Field plots were established in 1951-52 on Chehalis sandy loam soil to study the relation of several fertilizer treatments to germination. Plots were in randomized blocks of split-plot design with 5 replications of the fertilizer treatments each split into three parts for minor element leaf spray treatments.

Fertilizer treatments were as follows:

1. Check—no fertilizer.
2. Nitrogen only to supply 150 pounds per acre of the element, half as ammonium sulfate and half as sodium nitrate.
3. Nitrogen only at double the rates of treatment No. 2.
4. Nitrogen as in treatment No. 3 plus 100 pounds per acre of $P_2O_5$ at each spring application.
5. Nitrogen and phosphorus as in treatment No. 4 plus 50 pounds per acre of $K_2O$ at each spring application.

The fertilizers were sidedressed in three equal increments, the first in the fall as soon as the beets were large enough to cultivate, the second in early April and the third in early May. The phosphate was supplied from treble superphosphate and the potash from potassium chloride.

When the plants were well leafed out in the spring, spray treatments were superimposed on the fertilizer, as follows: 1. none (check); 2. polybore at 10 pounds per acre; and 3. sodium molybdate at 2 pounds per acre.

### B. Top Clipping Experiment.

A common practice among growers of table beet seed has been to clip the tips of the seed stalks when they are about 2 to 2½ feet high. This is alleged to induce branching and more uniform development and maturity

---

[1] Approved for publication as technical paper No. 831 by the Director of the Oregon Agricultural Experiment Station and the Chief, Field Crops Research Branch, Agricultural Research Service, United States Department of Agriculture. Sugar beet investigations in Oregon are conducted in cooperation with the Oregon Agricultural Experiment Station and Field Crops Research Branch, U.S.D.A.

[2] Agronomist Field Crops Research Branch Agricultural Research Service, United States Department of Agriculture.

[3] Numbers in parentheses refer ot literature cited.

of seed as well as increase yield. Transplanted table beets have been shown to develop relatively short thick fibrous root systems that do not anchor them well and such pruning may help to keep the beets from tipping out of the ground.

**Figure 1.—Root development of transplanted red beets. Note fibrous roots with not much anchor.**

There is some question as to whether or not the practice results in any improved seed yield or quality. A small field trial was made in 1950 to test the effect of tip pruning on yield of table beet seed. Four methods of pruning were used. Briefly, the results showed a reduced yield when the seed stalks were clipped back severely at about 12 to 15 inches high. Mild pruning of the tips when the plants were about 2½ feet tall had no effect on seed yield. Germination tests were not made on this seed.

Such top clipping has not been a practice with overwintered sugar beets for seed. Some growers have pastured weedy fields in early spring before seed stalks had made much development but the effects have not been measured.

Plots were set up within a randomized block design to test the effect of cutting back the tips of the seed stalks at two stages of growth on seed production. In one treatment, the stalks were tipped when about 8 inches high, and in the other case when they averaged about 2½ feet high. In each instance, from 2 to 4 inches of the tips were removed.

## Experimental Results

### A. Fertilizer Experiment.

Seed yield and germination percentage were determined. These are given in Table 1.

The very striking difference in yield between unfertilized and the 150-pound nitrogen rate was to be expected. Some highly significant additional yield was obtained from the double rate of nitrogen but there was no evidence of any benefit from phosphate. In a previous trial on similar soil, phosphate applied in the spring gave a consistent increased yield of about 400 pounds per acre (2). In this trial the potash treatment had a rather striking effect in making the seed stalks much stiffer so that they did not break over as did those with no potash.

Both boron as polybore and molybdenum spray treatments showed a trend toward higher seed yields but the differences were not significant in this trial.

**Table 1.—Effects of Fertilizers and Leaf Spray Treatments on Sugar Beet Seed Production.**

| Fertilizer Treatment | Yields (pounds per acre) Leaf Spray Treatments | | | |
|---|---|---|---|---|
| | Check | Polybore | Mb. | Mean |
| Check | 1,299 | 1,508 | 1,605 | 1,471 |
| $N_1$ | 3,235 | 3,299 | 3,323 | 3,286 |
| $N_2$ | 3,582 | 3,969 | 3,880 | 3,810 |
| $N_2P$ | 3,807 | 3,711 | 3,816 | 3,778 |
| $N_2PK$ | 3,985 | 3,969 | 3,920 | 3,958 |
| Means | 3,182 | 3,291 | 3,309 | |

Difference for significance at 5 percent level Fert. treat. 500 pounds.
Leaf spray treat. 308 pounds.

| | Germination (percent) | | | |
|---|---|---|---|---|
| Check | 86.6 | 85.2 | 84.6 | 85.5 |
| $N_1$ | 90.4 | 89.0 | 87.4 | 89.1 |
| $N_2$ | 92.0 | 90.6 | 92.4 | 91.7 |
| $N_2P$ | 93.4 | 93.4 | 93.6 | 93.5 |
| $N_2PK$ | 93.4 | 93.2 | 93.6 | 93.4 |
| Means | 91.2 | 90.3 | 90.4 | |

Difference for significance 5 percent level Fert. treat. 7.68 percent.
Leaf spray treat. N.S.

Nitrogen and phosphorus together produced a highly significant effect on seed quality as measured by germination, and there was some indication of improvement from nitrogen alone but not significant in this trial. There was no improvement in germination of the harvested seed due to the leaf spray treatments.

### B. Top Clipping Experiment.

Results of the clipping plots are given in Table 2. The data show clearly that clipping the tips of the sugar beet seed stalks at the later growth stage was injurious to both seed yield and germination. Clipping at an

earlier growth stage showed less positive evidence of a similar but less severe injury. Results of like nature were secured in a previous trial in 1944[4] in which the leaves were mowed off in early spring before the seed stalks were much in evidence.

**Table 2.—Effect of Clipping of Seed Stalk Tips on Seed Production.**

| Treatment | Seed Yield | Germination |
|---|---|---|
| | lbs. per acre | percent |
| None | 3,871 | 93.6 |
| Tipped at 8" height | 3,549 | 86.4 |
| Tipped at 24" height | 3,469 | 82.8 |
| 5% level significance | 372 | 4.37 |

## Summary

Field trials were established to test the effect of nitrogen, phosphorus and potassium on seed yield and germination of harvested seed.

Relatively low germination was obtained of seed that was produced without fertilizer other than sulfur and boron.

One hundred and fifty pounds per acre of nitrogen more than doubled the seed yield. Twice this amount of nitrogen produced more than 500 pounds additional increased yield.

When phosphate was added with the heavy nitrogen rate, germination of the seed produced was increased by 8 percent over the check treatment. Strong indications of improved germination were shown by the nitrogen alone treatments.

Spring leaf spray treatments produced no significant effect on either seed yield or quality as measured by germination.

Clipping the seed stalk tips when they were about 2 feet high, such as is commonly done with table beets, was detrimental to both seed yield and germination of the harvested seed.

[4] Unpublished data Soils Department, Oregon State College.

## Literature Cited

(1) HILLS, ORIN A., MCKINNEY, K. B. and PEAY, WALTER E.
1946. Lygus control in sugar beets grown for seed. Proc. ASSBT 4th general meeting, pp. 298-318.

(2) PENDLETON, R. A., FINNEL, H. E. and REIMER, F. C.
1950. Sugar beet seed production in Oregon. Ore. Exp. Sta. Bul. 437.

# Comparison of Hand and Machine Thinning of Sugar Beets[1]

ALBERT S. HUNTER AND JOHN A. YUNGEN[2]

In 1952 three experiments were conducted in Malheur County, Oregon, to compare the effects of hand thinning and machine thinning on yields of sugar beets. The use of mechanical thinners in this important beet growing area is increasing each year. Several demonstrations of machine thinning have been conducted by the Amalgamated Sugar Company, which operates in the area, but no replicated experiments had been previously carried out in Oregon to compare hand and machine thinning.

The data obtained in the three experiments are presented in Table 1.

## Furuyama Farm

On the Furuyama farm beets were planted during the last week of March in an excellent, smooth seedbed. Beets emerged evenly and were of uniform size. There were approximately 55 beet-containing inches per 100 inches of row. At thinning time a small amount of grass and very few weeds were present. Hand and machine thinning treatments were replicated 21 times in randomized blocks. Plots were 6 rows wide and 60 feet long.

**Table 1.—Summary of Data from Sugar Beet Thinning Method Experiments[1]**

| Thinning method | Beets/100 Ft. of row, Average | Average Spacing, Ins. | Beet Yield, T./A. | Percent Sugar | Lbs. Sugar/A. |
|---|---|---|---|---|---|
| | | **Furuyama Farm** | | | |
| | | **Means for 21 Replications** | | | |
| Hand | 105 | 11.4 | 28.9 | 17.6 | 10,100 |
| Machine | 99 | 12.1 | 27.8 | 17.3 | 9,570 |
| L.S.D. | N.S.[2] | N.S. | N.S. | N.S. | N.S. |
| | | **Bowers Farm** | | | |
| | | **Means for 16 Replications** | | | |
| Hand | 93 | 12.9 | 22.5 | 16.9 | 7,590 |
| Machine | 67 | 17.9 | 18.1 | 16.8 | 6,060 |
| L.S.D. | Sig.[3] | Sig. | Sig. | Sig. | Sig. |
| | | **Malheur Experiment Station** | | | |
| | | **Means for 10 Replications** | | | |
| Hand | 91 | 13.2 | 20.2 | | |
| Flex-heads | 154 | 7.8 | 21.6 | | |
| Flex-heads and knives | 125 | 9.6 | 19.8 | | |
| L.S.D. | | 1.6 | N.S. | | |

[1] Statistical Analyses by Dr. Jerome C. R. Li, Assoc. Prof. of Math., Oregon State College.
[2] N.S. = Differences not significant.
[3] Sig. = Differences significant at P = 0.05.

[1] Approved for publication as Technical Paper No. 850 by Director for the Oregon Agricultural Experiment Station and the Chief of the Soil and Water Conservation Research Branch, Agricultural Research Service, U.S.D.A. Contribution of the Department of Soils of OAES and of the Western Section of Soil and Water Management of SWCRB.

[2] Soil Scientist, Ore. Agr. Exp. Sta., and Western Section of Soil and Water Conservation Research Branch, SWCRB, ARS, USDA, cooperating, Corvallis, Oregon, and Research Assistant, Ore. Agr. Exp. Sta., Ontario, Oregon. We express our thanks to Jared Lewis and Henry Zobell of the Amalgamated Sugar Company Nyssa, Oregon, for their advice and interest in these experiments.

Hand thinning was done May 10 under supervision of one of the authors. After thinning there was an average stand of 105 beets per 100 feet of row; the average distance between beets was 11.4 inches.

Machine thinning was performed by the farmer, following his own schedule of operations. A 6-row rear-mounted Silver thinner was employed. Each unit was equipped with a gauge wheel to regulate depth of operation. Machine operations started May 10. The thinning machine was equipped with 16-tine flex-heads (spring tines from side-delivery hay rake) and the machine-thinned beets were gone over four times, as a preliminary to the thinning. These operations removed a few beets and nearly all grass. Following this the thinning heads were equipped with 8-blade knives (1¼ inches wide) and the plots were gone over twice. This was followed by two times over with the machine with heads equipped with 16-blade knives (⅝-inch wide). An average stand of 99 beets per 100 feet of row was obtained; the average spacing was 12.1 inches between beets. A week after thinning the beets were hoed one time with a long-handle hoe. No other hoeing was done. To control weeds and grass, all plots were later gone over with the thinning machine equipped with flex-heads.

As shown in Table 1, on the Furuyama farm there were no significant differences in the effects of hand and machine thinning on numbers of beets, percentage of sugar, or yield of beets or sugar per acre. The machine-thinned beets yielded 27.8 tons per acre.

**Bowers Farm**

Seedbed preparation and planting on the Bowers farm were performed by the farmer. Thinning was carried out under supervision of the authors. The seedbed was somewhat cloddy and dry. Emergence of beets was uneven; when the first beets to emerge were of a size suitable for thinning others were much too small. A considerable amount of grass was present. There were approximately 20 beet-containing inches per 100 inches of row.

Beets were planted March 26. Plots were 6 rows wide and 40 feet long. Thinning treatments were replicated 16 times in randomized blocks. Mechanical thinning operations began May 8, when the machine-thinned beets were gone over twice with 16-tine flex-heads on a 4-row trailing Silver thinner. This removed most of the grass and several of the small beets.

May 14 the plots were given a once-over treatment with 8-blade knives. This operation was followed May 17 by a treatment with 12-tine flex-heads, and May 22 by a treatment with 16-tine flex-heads. Many of the small beets were removed. The machine-thinned beets averaged 17.9 inches apart or 67 beets per 100 feet of row.

Hand-thinned beets were thinned May 8 to a stand averaging 12.9 inches apart, or 93 beets per 100 feet of row.

All plots were hoed with a long-handle hoe May 23. The machine-thinned plots required about one-fourth less hoeing than the hand-thinned plots. No other hoeing was done. All plots were gone over one time with flex-heads during the summer, to remove small grass and weeds.

The hand-thinned plots produced an average yield of 22.5 tons per acre. The machine-thinned plots gave a significantly lower yield of 18.1 tons. Sugar percentages were similar for both treatments. Total yield of sugar paralleled yields of beets.

### Malheur Experiment Station

Two methods of mechanical thinning were compared with hand thinning on the Malheur Experiment Station. On one case (A), thinning was performed with flex-heads only, in the other (B), by 8-blade knives after preliminary treatment with flex-heads.

Beets were planted April 1. After emergence there were approximately 28 beet-containing inches per 100 inches of row. Thinning treatments were replicated 10 times in randomized blocks. Plots were 4 rows wide and 90 feet long.

Light weedings were given all plots April 28 and 30 by going over them with flex-heads on a 4-row trailing Silver thinner.

The beets of one-third the plots were hand thinned May 23. The thinned beets averaged 13.2 inches apart, or 91 beets per 100 feet of row.

On one-third the plot thinning was accomplished with flex-heads only. The plots were gone over twice with 12-tine and once with 16-tine flex-heads between May 14 and 21. After thinning there were 154 beets per 100 feet of row; the average distance between beets was 7.8 inches.

Thinning of the beets of one-third of the plots was accomplished with a combination of flex-heads and knives. Between May 14 and 21 the plots were gone over twice with 16-tine flex-heads, once with 8-blade knives (1¼ inch blades), and once with 12-tine flex-heads. The stand of beets averaged 125 beets per 100 feet of row; 9.6 inches was the average distance between beets.

Plots of both mechanical thinning treatments were gone over with 16-tine flex-heads June 4. All beets were given one hoeing with long-handle hoes June 6.

There were no significant differences between yields of beets from plots of the three thinning treatments. The highest yield recorded was from the plots thinned with flex-heads only.

### Summary and Conclusions

Hand and machine thinning (Silver thinner) of sugar beets were compared in three experiments. Where the beets were planted in a good seedbed and emerged evenly, yields of machine-thinned and hand-thinned beets were not significantly different. Where the seedbed was cloddy and dry, and emerged uneven, hand-thinned beets yielded significantly more than machine-thinned beets. Thinning method had no effect upon sugar content of the beets.

# Sugar Beet Planting Date Studies in Imperial Valley, California

CHARLES PRICE, DON FIFE, AND B. A. KRANTZ[1]

Imperial Valley, because of its fertile soil and relative mild winter climate, was considered a potential beet-growing area some time before beets were planted there on a commercial scale in 1937. Numerous small experiments were conducted in an effort to determine cultural practices best suited for growing the crop, but the sugar beet varieties in early experimental tests proved unsuitable for sugar production because they bolted too much. Curly-top resistant and other varieties were being planted in the Salt River Valley of Arizona for seed production by the field overwintering method only about six to eight weeks earlier than the planting dates for sugar production in the Imperial Valley. Since the winters in the Arizona seed districts are not much colder than are those of Imperial Valley, it is easy to understand why the varieties used went to seed. It became evident from the early tests that non-bolting varieties were necessary if sugar beets were to be grown for sugar in Imperial Valley.

In 1939 the senior author in cooperation with Holly Sugar Corporation and Harold Hunt conducted a planting date test near Holtville, California, on Mr. Hunt's ranch. In this test five varieties of sugar beets were planted at approximately monthly intervals in replicated plots beginning May 1 until October. The results of this test showed that sugar beets could be grown successfully in the Imperial Valley under a wide range of planting conditions. It was evident, however, that a variety with low bolting tendency and resistance to curly top was required if sugar beets were to compete with other agricultural crops growing in Imperial Valley. U. S. 15 had low bolting tendency and was moderately resistant to curly top, which made it the dominant choice for fall seeding in Imperial Valley. However, U. S. 56/2, a variety more recently developed, has now replaced U. S. 15 because of its superior yield under Imperial Valley conditions.

When non-bolting varieties became available, sugar beet production in Imperial Valley became stabilized, the successful practice being fall planting with harvest in May or June of the next year. Fall planting seemed preferable for sugar beets, and acreages increased. A beet sugar factory was built in 1947. It then became apparent that, for most efficient factory operations, large acreages with harvest spread over a considerable period were desirable. For growers to obtain satisfactory returns, the growing season needs to be long, and this puts limits on the period of harvest. Thus it was found that October-planted beets are not ready for harvest before the following May, and consequently the earlier harvest would be possible only if the beets were planted earlier than was the practice.

There is also a limit on extending the harvest into the summer. Records of Holly Sugar Corporation show that if the harvest period extends beyond

[1] Agronomist, Field Crops Research Branch, Agr. Research Service, U. S. Department of Agriculture, Riverside, California; Agricultural Aid, Field Crops, Research Branch, Agr. Research Service, U. S. Department of Agriculture, Brawley, California, and Senior Soil Scientist, Department of Agriculture, Brawley, California.

mid-July, there is a decline in acre yields of sugar. This decline seems to be due principally to reduction in the sucrose percentage of the beets. It seemed, therefore, advisable to explore the possibility of planting beets earlier than was the practice so that the beet harvest could be completed before decline in sugar per acre yield occurs. A preliminary test by the senior author was conducted in 1950 to study these possibilities, but because of excessive damage from insect pests and high alkali concentration of the soil, the results of this test were not considered reliable.

Another test was conducted in 1951 under more favorable conditions, the results of which are reported here. The 1951 test was conducted at the Southwestern Irrigation Field Station, Brawley, California, on Holtville silty clay loam soil. The test consisted of five varieties planted in plots replicated four times at six different dates as follows: July 16; August 1, 15, and 31; September 14, and October 1, 1951. The beets were planted in six-row plots 62 feet long on beds 30 inches apart with one row per bed. Whole seeds were planted approximately one inch deep and at the rate of approximately 15 pounds per acre. The fertilizer program consisted of an application of 103 pounds of 13-39-0 per acre at seeding time, 80 units of nitrogen at thinning time, and a later application of 85 units of nitrogen.

The beets in each planting date were thinned at about the 8-leaf stage. Irrigation water was applied to the beets when need was evident. Pest control was found to be very important in the summer-planted beets, principally because there were not many crops growing during the summer and the insects seemed to concentrate on the small plot of beets. The experience in 1953 indicates that more difficulty from insects will probably be encountered with summer-planted sugar beets than with those planted in October.

Because of the excessive bolting that occurred in four of the five varieties used in this test (Figure 1) and the consequent deleterious effect on yield and sucrose percentages, only the yields and sucrose percentages of U. S. 56/2, a non-bolting variety, are reported here.

Excessive bolting in a variety eliminates it as a candidate for fall planting in Imperial Valley, but in spite of this showing with beets that were harvested in May, easy-bolting varieties of sugar beets may be used under some conditions for summer planting. The important consideration is that the harvest of these easy-bolting varieties may be completed early in the spring before normal bolting in sugar beets occurs. Tests are currently under way in the Imperial Valley designed to study the possibility of using easy bolting varieties suitable for summer planting, by avoiding loss from bolting by means of a March or early April harvest.

The sugar beets from plots planted July 16, August 1 and August 15, 1951, were sampled March 10 and April 7, 1952. There were no yields taken at these two sampling dates, because there were not sufficient beets in the plots for obtaining yield data at these two periods and at the final harvest.

Sucrose percentages were determined, however, and they were about equal to the sucrose percentages of the beets harvested May 7, 1952. The roots taken March 10 and April 7 for sucrose analysis were somewhat smaller

**Figure 1.—A view of a portion of the experimental field at harvest time, May 5, 1952. Plot in middle foreground which is free from bolting was planted July 16, 1951, with U. S. 56/2. Note excessive bolting in other varieties in the test.**

than those harvested May 7, and consequently the yields at the early dates would have been lower. On May 7, 1952, sugar beets in all plots of all planting dates were harvested, and yield and sucrose percentages determined. Roots were taken only from measured areas in which the plants had competition on all sides. The middle four rows in each of the four replications of each planting date were harvested for yield and sucrose data. Yields as obtained from weights of beets from the measured areas were calculated to an acre basis. The sucrose determinations were based on two 10-beet samples taken at random from each plot. Results of this test are shown in Table 1.

The results of this test show that sugar beets planted in July and August and harvested in early May yielded significantly higher than beets planted September 14 or October 1, which correspond to the usual planting time for the Imperial Valley. It is further shown that on the May 7 harvest the differences in sucrose percentages of the beets for the various planting dates were small; the July 16 planting, however, was significantly high in three cases.

It would seem from the results of this experiment that sugar beets can be planted successfully in July and August in the Imperial Valley, and that these early-planted beets can be harvested earlier than is the current practice. Earlier plantings would permit prolonging the sugar beet harvest period, resulting in higher returns to both gower and processor. Advancing the planting date would make it possible to complete the harvest before late June or July, when reduction of the sucrose content in the beet may occur.

**Table 1.—Effects of Date of Planting on the Acre Yield and Sucrose Percentage of Sugar Beet Variety U. S. 56/2 in the Imperial Valley, California, 1951-52.**

4 Replicated Plots of Each Planting Date. Harvested: May 7, 1952

| Planting Date | Acre Yield | | Percent Sucrose |
|---|---|---|---|
| | Gross Sugar Tons | Tons Beets | |
| 7-16-51 | 5.89 | 36.21 | 16.27 |
| 8- 1-51 | 5.93 | 37.87 | 15.67 |
| 8-15-51 | 5.54 | 36.79 | 15.05 |
| 8-31-51 | 5.63 | 37.10 | 15.17 |
| 9-14-51 | 4.85 | 30.96 | 15.62 |
| 10- 1-51 | 3.87 | 25.59 | 15.22 |
| Sig. Diff. 5% point | .46 | 2.42 | 1.05 |

# Experiences with Sugarbeet on Land Flooded by the Sea

H. Rietberg[1]

On Feb. 1, 1953, large areas in the Netherlands, Belgium and England were flooded by the North Sea. The tides reached a level which had not occurred for ages and seawalls were broken in many places. The floods reached far inland, and since the water level in the river estuaries was low, saltwater came up the rivers much farther than with normal tides.

In the Netherlands, about 340,000 acres were flooded in the southwest part of the country both on the mainland and on the islands. This area (situated from 1-15 feet below sea level) largely consists of clay and silt soils reclaimed from the sea and is considered as one of our best areas for agricultural purposes.

Sugar beets have been grown in this area for more than 100 years. The tonnage per acre is high, with 18 tons per acre as a normal 10-year average and up to 30 tons in good years on the best farms.

In normal years, in this flooded area, about 35,000 acres of sugarbeet are grown. This catastrophe gravely influenced the situation for the sugar factories in this area and the sugar production of the country was expected to suffer severely. To our pleasant surprise, a very good crop (18 tons per acre for the total acreage of the Netherlands) and a considerable increase in acreage in the east part of the country outweighed the loss in the western area.

It was necessary to bring the land back into production as quickly as possible. As soon as the water had been drained from a certain area, soil samples were taken and the salt content determined. Near the sea the salt content was found to be very high but more inland, it decreased gradually, more or less in proportion with the salt content of the floodwater. Since the 1953 spring period was abnormally dry, the salt was not washed down by rain and in early summer a white crust of salt covered many fields.

Barley can be cultivated better than other crops on soils of high salt content; therefore, a large acreage of barley was sown. Sugar beets, also fairly resistant to salt, were planted on about 15,000 acres from which approximately 12,000 acres were harvested. The other 3,000 acres gave little, if any yield, mainly for the following reasons:

1. No germination at all, due to the high salt content, poor soil structure or a combination of both.
2. Seedlings killed by drought in May, aggravated by the increase in salt content.
3. Very slow growth during the season, resulting in few marketable beets at harvest.

A very interesting phenomenon occurred around the middle of June when the long period of dry weather was suddenly broken by heavy rain storms. Everybody expected the moisture to be favorable to the crops, espe-

[1] Director, Instituut voor Rationele Suikerproductie, Bergen op Zoom, Netherlands.

cially on the salt land. Within 24 hours and very unexpectedly, many farmers were alarmed to find beets completely collapsed—even those which had been growing unexpectedly well. Investigation showed that the plants had bcome more or less "adapted" to the high concentration of salt in the soil solution. This sudden dilution of the salt concentration permitted the plants to take up more water than could be absorbed by the plant tissue, causing the cells to burst. In many roots the central cylinder was loosened from the surrounding tissue, permitting bacteria and fungi to invade the plants, causing the death within a few days. In some fields, nearly all of the plants died, in other fields, the larger plants survived, leaving fields with long gaps and poor stands.

On many fields later in the summer, plants were found with symptoms characteristic of calcium deficiency, even though these soils are rich in calcium carbonate. The same was experienced years ago with beets on the island of Walcheren which was flooded during the last war. Analysis then and now showed that these beets had a normal calcium content but the sodium content was increased to 300-400 percent of normal. It was concluded that calcium deficiency was relative and not direct and was eventually talked of as a sodium toxicity, indicating that the balance between calcium and sodium in the plant had been upset.

Many fields in the flooded areas showed a much higher percentage of virus yellows than fields on the neighboring "dry" land. In part, this was due to late drilling and open stands, which in our country foster the development of this disease. With only beets and barley growing in those areas, it was found that aphids concentrated on the beet crop.

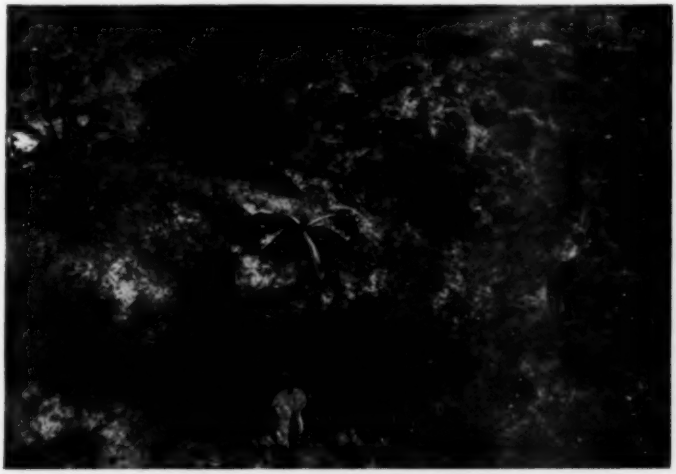

**Figure 1.—Young beet plants killed by rain. (See text).**

Yields varied from 16 tons on land with low salt content to 3 tons on salt land. In general, the sucrose content was 1½-2 percent lower than normal.

Processing of these beets caused difficulties, with lower purity and a high production of molasses. It was difficult to store these beets. They have a tendency to spoil very rapidly since the whole enzymatic system in the root is out of balance. The same was true for mangolds in these areas, which is evidenced by reports that many clamps are 100 percent spoiled.

The soil complex is still saturated with sodium in these areas and, from past experience, we must expect a poor quality beet for several years to come. It is expected that at least 30,000 acres of beets are to be grown in these areas in 1954, which proposes quite a headache for some of our factories.

# Sugar Losses Caused by Frost Defoliation

F. H. PETO[1]

## Introduction

A previous study (1)[2] of twenty years' results at the Raymond factory showed that the sugar content on the average rose 0.78 percent in the 10-day period preceding a frost of 26° F. or lower, and fell 0.24 percent within ten days subsequent to frost. A further study (2) involving the freezing of sugar beet tops by covering the beets with an insulated box containing dry ice, showed a reduction in sugar content of 1.43 and 2.3 percent two weeks after freezing.

It was well known that defoliation caused by both frost and the knife would stimulate new bud and leaf formations, and that the resulting rapid growth would tend to decrease the sugar stored in the root. However, the possibility existed that the two methods of leaf destruction could differ, in that substances from the frozen leaves could be translocated to the crown and root and induce changes at least differing in degree from those resulting from cutting off the leaves.

The present experiment compares the sugar losses caused by freezing the tops with those caused by cutting off the leaves and petioles with a knife.

## Methods

The sugar beets used in these experiments were planted in the field May 20, 1953, and subsequently thinned to eight-inch spacings. Each plot was limited to four beets to facilitate freezing in the field. There were four replicates each of twelve treatments arranged in a randomized block design.

Freezing and knife defoliation were done September 9 with harvesting and sampling for analysis following after the intervals indicated in Table 1.

The method of freezing consisted of covering the plot of four beets in the field with an insulated box 40x14x16 inches. Wire mesh trays containing 60 pounds of dry ($CO_2$) ice were placed on a rack in the upper portion of the box. A 13-minute treatment period was found to be adequate to freeze the leaves completely, together with varying proportions of the petioles. The exposed crowns showed no sign of having been frozen.

Defoliation consisted of cutting off the leaves and petioles with a knife just above the crown without damage to the crown.

The beets were dug at the times indicated, and the crowns and tops were cut off as in commercial topping. Storage, where necessary, was done by packing the topped beets from each plot in a paper bag and a carton containing these samples was placed in refrigerated storage at approximately 36° F. for the ten-day storage period. The beets were weighed just prior to sampling for sugar and purity.

---

[1] Director of Agricultural Research, British Columbia Sugar Refining Company Limited, Vancouver, B. C.

[2] Numbers in parentheses refer to literature cited.

## Discussion

In Table 1, the data is arranged to compare the general average of the four freeze, defoliate (knife) and check treatments. There was no significant difference beteen treatments in either root weight or purity. Freezing and defoliation with the knife caused significant average reductions of 1.56 and 1.74 percent respectively, in the sugar content, as compared to the check. Detailed examination of this table will show that the freezing and knife defoliation gave very similar sugar contents for comparable pre- and post-harvest treatments. We, therefore, conclude that the loss of the leaves was the primary cause of the sugar loss and it made no difference whether this leaf loss was accomplished by use of frost or the knife.

The data presented in Table 2 compare the sugar losses between two and twelve days' regrowth after treatment. It is interesting to note that the average loss per day was almost identical, being 0.20 percent for two days' regrowth and 0.24 percent for twelve days' regrowth. This indicates the sugar losses were in evidence very shortly after top destruction, and continued at the same rate per day for the period under test.

**Table 1.**

| No. | Treatment | Harvested (Days After Treat.) | Storage (Days) | Ave. Root Weight | Percent Sugar | Purity |
|---|---|---|---|---|---|---|
| 1. | Freeze | 2 | nil | 13.2 | 14.73 | 88.0 |
| 2. | Freeze | 2 | 10 | 13.0 | 14.90 | 88.3 |
| 3. | Freeze | 12 | nil | 11.6 | 13.50 | 87.9 |
| 4. | Freeze | 12 | 10 | 11.0 | 13.65 | 84.2 |
| | | | Ave. | 12.2 | 14.19 | 87.1 |
| 5. | Defoliate (knife) | 2 | nil | 11.4 | 14.28 | 84.8 |
| 6. | Dfoliate (knife) | 2 | 10 | 12.2 | 15.48 | 89.2 |
| 7. | Defoliate (knife) | 12 | nil | 12.9 | 13.15 | 88.3 |
| 8. | Defoliate (knife) | 12 | 10 | 14.6 | 13.14 | 85.2 |
| | | | Ave. | 12.8 | 14.01 | 86.9 |
| 9. | Check | 2 | nil | 12.3 | 14.95 | 86.1 |
| 10. | Check | 2 | 10 | 11.0 | 15.54 | 87.9 |
| 11. | Check | 12 | nil | 13.8 | 15.85 | 88.9 |
| 12. | Check | 12 | 10 | 9.5 | 16.68 | 86.4 |
| | | | Ave. | 11.7 | 15.75 | 87.3 |

**Table 2.—Percent Sugar Losses Resulting from Freezing and Cutting-off Foliage as Compared to the Checks.**

| Treatment Comparisons | Sugar Loss Two Days' Regrowth | Treatment Comparisons | Sugar Loss Twelve Days' Regrowth |
|---|---|---|---|
| | % | | % |
| 9-1 (ck-freeze) | 0.22 | 11-3 (ck-freeze) | 2.35 |
| 9-5 (ck-defoliate) | 0.67 | 11-7 (ck-defoliate) | 2.70 |
| 10-2 (ck-freeze) | 0.64 | 12-4 (ck-freeze) | 3.03 |
| 10-6 (ck-defoliate) | 0.06 | 12-8 (ck-defoliate) | 3.54 |
| Ave. | 0.4 | Ave. | 2.9 |
| Ave. per day | 0.2 | Ave. per day | .24 |

Table 3.

| No. | Treatment | Harvested (Days After Treat.) | Storage (Days) | Ave. Root Weight | Percent Sugar | Purity |
|---|---|---|---|---|---|---|
| 1. | Freeze | 2 | nil | 13.2 | 14.73 | 88.0 |
| 5. | Defoliate (knife) | 2 | nil | 11.4 | 14.28 | 84.8 |
| 9. | Check | 2 | nil | 12.3 | 14.95 | 86.1 |
| | | | Ave. | 12.3 | 14.65 | 86.3 |
| 2. | Freeze | 2 | 10 | 13.0 | 14.90 | 88.3 |
| 6. | Defoliate | 2 | 10 | 12.2 | 15.48 | 89.2 |
| 10. | Check | 2 | 10 | 11.0 | 15.54 | 87.9 |
| | | | Ave. | 12.1 | 15.31 | 88.4 |
| 3. | Freeze | 12 | nil | 11.6 | 13.50 | 87.9 |
| 7. | Defoliate | 12 | nil | 12.9 | 13.15 | 88.3 |
| 11. | Check | 12 | nil | 13.8 | 15.85 | 88.9 |
| | | | Ave. | 12.7 | 14.17 | 88.4 |
| 4. | Freeze | 12 | 10 | 11.0 | 13.65 | 84.2 |
| 8. | Defoliate | 12 | 10 | 14.6 | 13.14 | 85.2 |
| 12. | Check | 12 | 10 | 9.5 | 16.68 | 86.4 |
| | | | Ave. | 11.7 | 14.49 | 85.3 |

In Table 3 the data are arranged to illustrate the effect of ten-days' storage at approximately 36° F. In spite of the fact that the storage difference was not significant, the beets had a higher sugar content after ten days' storage than at harvest for five out of six comparisons. For beets harvested two days after treatment, this difference was 0.66 percent, and for beets harvested twelve days after treatment, it was 0.32 percent. Preharvest treatments had no effect on the sugar gain in storage. The cause for this increase is unknown, but unexpected dessication of the roots is the most plausible explanation.

The original suggestion that freezing of the leaves might induce physiological changes in the roots as distinct from those resulting from knife defoliation has now been disproved for the conditions of these treatments. It might be assumed, therefore, that sugar losses were caused by the energy consumed by regrowth of new tops. While this undoubtedly does occur where temperatures after freezing are sufficiently high to permit growth, it does not explain sugar losses in a year such as 1951 at Taber, Alberta, where heavy frosts and snow occurred October 5, and the average temperature (mean of daily maximum and minimum) did not again rise above freezing until November 5. No regrowth whatever was possible during this period and yet the sugar content for the five-day factory average fell steadily from 15.95 and 15.31 percent as illustrated in Figure 1. For the same period during the 1953 harvest, the temperatures remained high with no frost, and the sugar content rose steadily from an average of 16.83 percent for the period October 10-14 to a high of 17.45 for October 25-29. These observations lead us to believe that heavy frosts which penetrate the crown may be capable of reducing the sugar content even though regrowth is impossible because of freezing temperatures.

Wood (3) reported a sharp drop in sugar content following a frost of 15° below zero F. at Longmont, Colorado, in 1951. This drop was not associated with new foliar growth.

Evidence, therefore, is now available from several sources which shows that severe freezing of beets in the field can cause severe sugar losses not associated with regrowth.

The search should be continued to determine the nature of the physiological processes involved in such losses which in certain years are probably quite severe in the more northerly beet growing areas.

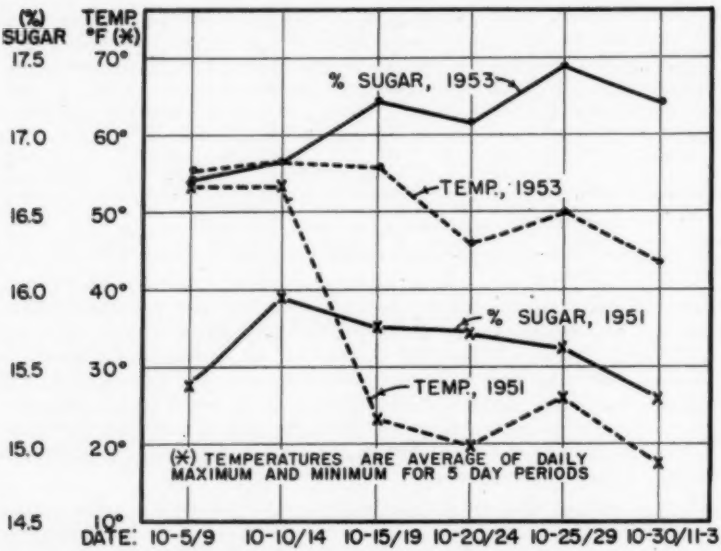


**Figure 1.—Relation of temperature to percent sugar.**

## Conclusions

1. Freezing and cutting off of the leaves and petioles resulted in similar and significant reductions in sugar content averaging 1.56 and 1.74 percent respectively, less sugar than the checks.

2. The average loss of sugar from the combined results of cutting off and freezing of the foliage was 0.4 or 0.2 percent per day for two days' regrowth as compared to 2.9 or 0.24 percent per day fo twelve days' regrowth. This indicates that sugar losses were in evidence very shortly after top destructions and continued at about the same rate per day for period under test.

3. Neither freezing nor cutting off of the foliage caused any observable reduction in root weight or purity.

4. Cold storage of all treatments for ten days after commercial toppings (crown removal) resulted in increases in the sugar content of 0.66 percent in treatments harvested two days after treatment and 0.32 percent in beets harvested twelve days after treatment.

## Literature Cited

(1) PETO, F. H.
1952. Effect of frost on sugar contents in beets. Proc. American Society of Sugar Beet Tech. pp. 108-111.

(2) PETO, F. H., SMITH, W. G., and LOW, F. R.
1952. Effects of pre-harvest sprays of Maleic Hydrazide on sugar beets. Proc. Am. Society of Sugar Beet Tech. pp. 101-107.

(3) WOOD, R. R.
1952. Selection for cold tolerance and low temperature germination in sugar beets. Proc. Am. Soc. of Sugar Beet Tech. pp. 407-410.

# The Influence of Maleic Hydrazide on Bolting and Yield of Overwintered Sugar Beets in California

D. Ririe, L. M. Burtch, and F. J. Hills[1]

## Introduction

The increased tendency to overwinter sugar beets as practiced in recent years in California has resulted in more interest in the problem of bolting. Price, *et al.*, (5)[2] pointed out that reduction in root size, difficulty of processing at the factory, decreased sugar content, volunteer beets, and interference with mechanical harvest might all be objectionable results of bolting in fields planted for sugar production. Of the reasons mentioned above, decreased sugar content, harvest interference and processing difficulties were the most seriously considered as reasons for these studies.

Previously reported literature dealing with other plant species suggested that maleic hydrazide might prove to be a suitable growth regulator in delaying or preventing bolting. Jackson and Wittwer (2) reported a significant reduction of seed stalk formation of celery when maleic hydrazide sprays were applied to the maturing crop. Choudhri and Bhatnagar (1) referred to data showing reduction of bolting in onions as a result of the action of the same chemical.

Mikkelsen, *et al.*, (3) reported sugar content improvement in sugar beets as a result of foliar maleic hydrazide sprays. Peto, *et al* (4) reported results with maleic hydrazide which indicated a significant increase in sugar content and a yield reduction from applications at an early spray date related to the harvest period. Stout (6) reported no evidence in certain studies for sugar accumulation as a result of foliar application of maleic hydrazide.

A growth-regulating material such as maleic hydrazide could be of considerable value in overwintering beets, if bolting could be stopped or retarded and production increased by its use. The following series of experiments was, therefore, initiated to test the effect of maleic hydrazide on overwintered sugar beets with respect to sugar content, growth and bolting.

## Methods

Four fields were selected in three sections of California in which beets overwinter. The sections were the Imperial Valley, Firebaugh, located in the San Joaquin Valley, the Dixon-Davis area of the Sacramento Valley. In each field foliar sprays of maleic hydrazide were superimposed on vigorously growing beets. In the Firebaugh and Imperial Valley tests maleic hydrazide 30 was used with wetting agents; in the other test maleic hydrazide 40, containing a wetting agent, was used.

The principal variations in treatment were time of application, time of harvest, and in the Imperial Valley, rate of material applied. The treatments in all experiments were applied by hand with a knapsack-type sprayer

---

[1] Assistant Agronomist, University of California; Agronomist, Spreckels Sugar Company; and Extension Agronomist, University of California, respectively.

[2] Numbers in parentheses refer to literature cited.

at a rate of 50 gallons per acre. Observations and bolting counts were taken as conditions warranted and each plot was harvested on an area basis. From two to four sugar samples were taken from each plot in each replication at each harvest date. The following items of data were reported for each experiment: percent bolting, percent sucrose, tonnage of beets, and pounds of sugar per acre.

There were minor variations in procedure which will be discussed separately for each experiment.

In the Imperial Valley three concentrations of maleic hydrazide sprays were applied at three dates prior to harvest. The test included ten treatments replicated six times. The beets selected were from a commercial planting of variety U. S. 56, seeded in August, 1951. Between the date of the first spraying, March 19, and the harvest date, May 7, 1952, a considerable percentage of the beets bolted.

The next experiment was located near Dixon, California, and was established on beets of variety U. S. 56/2 planted August 1, 1952, and harvested the following spring. The field was in good condition at the start of the experiment, but the beets were small in size because of growing season limited by cold temperatures and short day length. The treatments included maleic hydrazide application on March 4, 14, and 25, and an undisturbed check arranged as a 4 x 4 Latin square. These main plots were split for dates of harvest in strips across the four applications. There was no indication of bolting at any of the spray dates.

The dates of harvest were: April 3, before bolting signs appeared; April 15, at the start of bolting; and May 22, when bolting in the untreated check reached 90 percent.

The remaining experiments were established on variety U. S. 22/3 planted May, 1952, near Davis, California, and on variety S-2[a] planted August, 1952, near Firebaugh, California. In each experiment a two-pound rate of maleic hydrazide was compared with an undisturbed check. Each treatment was replicated six times. In the Firebaugh test, maleic hydrazide was applied to the beets February 17, 1953, before bolting signs appeared, and the beets were harvested April 10, 1953. The sugar beets near Davis were sprayed March 14 shortly after bolting had started, and were harvested April 13, 1953.

## Results

The yield and bolting data of the Imperial Valley experiment are reported in Table 1.

The most effective treatment was the two-pound per acre rate applied seven weeks prior to harvest, which resulted in a significantly lower percent of bolters and an accompanying rise in sugar content. This effect diminished as the concentration of material applied at the first harvest date was decreased. The sugar content of beets sprayed three weeks and one week prior to harvest was not influenced significantly regardless of the rate ap-

[a] S-2 is a bolting resistant selection from U. S. 22/3.

plied. There was no significant effect on root yield. At the last two harvest dates there was no significant effect on sugar production, but, beets sprayed March 19, when compared at all three rates with the check, showed a significant increase in sugar yield. The sugar production of beets sprayed at the first date was significantly better than that of beets sprayed at the last two dates.

The results of the Dixon experiment appear in Table 2.

**Table 1.—The Effect of Maleic Hydrazidel Sprays on Yield, Percentage of Sucrose, and Bolting of Beets. Imperial Valley Test, Planted August, 1951. Harvested May 7, 1952.**

| MH treatment lbs./acre[1] | Date of Spray | Weeks prior to Harvest | % Sucrose | Yield | | % Bolters |
|---|---|---|---|---|---|---|
| | | | | Roots (tons/acre) | Sugar[2] (lbs./acre) | |
| 2 | Mar. 19 | 7 | 18.8 | 19.9 | 7,460 | 7 |
| 1 | Mar. 19 | 7 | 18.2 | 19.8 | 7,200 | 25 |
| ½ | Mar. 19 | 7 | 18.0 | 20.5 | 7,380 | 33 |
| 2 | Apr. 16 | 3 | 17.8 | 19.5 | 6,940 | 34 |
| 1 | Apr. 16 | 3 | 18.1 | 19.3 | 6,960 | 36 |
| ½ | Apr. 16 | 3 | 17.9 | 19.6 | 7,040 | 40 |
| 2 | Apr. 30 | 1 | 17.4 | 21.0 | 7,340 | 33 |
| 1 | Apr. 30 | 1 | 17.6 | 19.1 | 6,720 | 37 |
| ½ | Apr. 30 | 1 | 17.8 | 19.7 | 7,040 | 35 |
| Check | | | 17.6 | 19.4 | 6,820 | 40 |
| L.S.D. Odds 19:1 | | | 0.4 | N.S. | N.S. | 7 |

[1] Pounds of active ingredient, formulation M.H. 30.
[2] A comparison of maleic hydrazide at the first spray date versus the latter spray dates or the check indicated a significant sugar yield improvement.

**Table 2.—Effect on Yield and Sucose Percentage of Maleic Hydrazide at the Rate of Two Pounds Active Ingredient Per Acre Applied to Foliage of Sugar Beets on Three Dates. Beets Planted August 1, 1952, Near Dixon, California.**

| Harvest date | Dates of Application | Weeks prior to Harvest | % Sucrose | Yield | | %[1] % Bolters |
|---|---|---|---|---|---|---|
| | | | | Roots (tons/acre) | Sugar (lbs./acre) | |
| Apr. 3 | Check | — | 14.9 | 11.8 | 3,520 | — |
| | Mar. 4 | 5 | 15.6 | 13.2 | 4,120 | — |
| | Mar. 14 | 3 | 15.5 | 12.4 | 3,840 | — |
| | Mar. 25 | 1 | 15.0 | 12.6 | 3,780 | — |
| Apr. 15 | Check | — | 16.3 | 12.6 | 4,100 | — |
| | Mar. 4 | 7 | 17.1 | 12.5 | 4,280 | — |
| | Mar. 14 | 5 | 16.8 | 12.7 | 4,270 | — |
| | Mar. 25 | 3 | 16.7 | 11.7 | 3,910 | — |
| May 22 | Check | — | 14.6 | 14.6 | 4,260 | 90 |
| | Mar. 4 | 12 | 15.0 | 14.1 | 4,240 | 60 |
| | Mar. 14 | 10 | 14.8 | 14.9 | 4,410 | 57 |
| | Mar. 25 | 8 | 15.3 | 14.3 | 4,370 | 49 |
| L.S.D. Odds 19:1 | | | N.S. | N.S. | N.S. | 11 |

[1] Bolting was negligible at the April 3 and 15 harvests.

Bolting was of no consequence in either treated or check plots for the April 3 and 15 harvests. It can be seen from the results of the April 3 harvest that sucrose percentages were apparently increased in the plots sprayed with maleic hydrazide March 4 and 14, but no increase resulted from beets

sprayed March 25. The second harvest was completed April 15. An increase in sucrose percentage was found on beets sprayed at all three dates in comparison with untreated beets. The apparent increase in sucrose percentage at these harvest dates approached significance, but was not significant at the 5 percent level.

By the final harvest date, May 22, bolting had become a significant factor. All treatments were showing visible bolters with those in the check showing 12-18 inches higher than those in the treated plots. The untreated beets averaged 90 percent bolters May 21 as compared with 60, 57, and 49 percent respectively for the three dates of spraying. The differences between dates of spraying could be detected by the eye. As indicated by Figure 1, bolting was higher at the final harvest date than had been observed two weeks earlier.

**Figure 1. Bolting was reduced by maleic hydrazide from the standpoint of time of appearance, total number of bolters, and size and condition of bolters at harvest time. The sucrose percentage, however, was not significantly increased by maleic hydrazide in the final harvest. Thus from the results of this test it would appear that maleic hydrazide benefits were derived from its ability to delay bolting by three to four weeks.**

**It is apparent from Table 2, however, that date of harvest did have an influence on yield of untreated beets. The data for the three harvests of this treatment are summarized in Table 3 for easier comparison.**

**Table 3.—The Effect of Time of Harvest on Overwintered Beets. Planted August 1, 1952, Near Dixon, California.**

| Date of harvest | Percent sugar | Yield | | % Bolters |
|---|---|---|---|---|
| | | Roots (tons/acre) | Sugar (lbs./acre) | |
| Apr. 13 | 14.9 | 11.8 | 3,520 | None |
| Apr. 15 | 16.3 | 12.5 | 4,010 | Starting |
| May 22 | 14.6 | 14.6 | 4,260 | 92% |
| L.S.D. Odds 19:1 | 0.3 | 1.1 | N.S. | |

It is evident from table 3 that tonnage of beets increased consistently between April 3 and May 22. The percent sucrose also increased signif-

icantly between April 3 and 15, but decreased between April 15 and May 22. This decrease in sucrose percentage is probably the result of seed stalk formation and/or increased beet growth. Yields of sugar, however, did not increase significantly between April 3 and May 22. From the standpoint of most efficient harvest, April 15 seemed to be the most effective harvest date.

Similar results were obtained from the Davis and Firebaugh tests. Bolting was significantly reduced by the maleic hydrazide in both of these tests; sucrose percentage was increased but yields in tons of beets and sugar per acre were not significantly affected.

The results from the Firebaugh test appear in Table 4.

**Table 4.—The Effects of a Two-Pound Per Acre Application of Maleic Hydrazide Applied as a Foliage Spray to Sugar Beets Planted August 10, 1952, Near Firebaugh, California. (Sprayed February 17, 1953. Harvested April 10, 1953.)**

| | | Yield | |
|---|---|---|---|
| | Sucrose Percentage | Roots (tons/acre) | Sugar (lbs./acre) |
| Check | 14.1 | 16.4 | 4,630 |
| Treated | 16.2 | 17.4 | 5,640 |
| L.S.D. Odds 19:1 | 0.8 | N.S. | N.S. |

In this test it can be seen that the results considerably favor the treated plots. In addition to the sucrose percentage increase, bolting was stopped almost completely in the treated plots until the time of harvest: on April 10 there were no bolters showing above the foliage in the treated plots as compared to approximately 50 percent visible bolters in the untreated plots. The yield differences were not statistically significant, however.

The results from the Davis test appear in Table 5.

**Table 5.—The Effect of a Two-Pound Per Acre Application of Maleic Hydrazide Applied as a Foliage Spray to Sugar Beets Planted May, 1952, near Davis, California. (Sprayed Mach 14, 1953. Harvested April 13, 1953).**

| | | Yield | | Ave. No. bolters per 100' of row |
|---|---|---|---|---|
| | Sucrose Percentage | Roots (tons/acre) | Sugar (lbs./acre) | |
| Check | 16.0 | 15.5 | 4,970 | 93 |
| Treated | 17.0 | 14.8 | 5,020 | 44 |
| L.S.D. Odds 19:1 | 0.7 | N.S. | N.S. | |

It was observed in this test that spraying maleic hydrazide after bolting had started was effective in reducing the total number, size, and appearance of seed stalks in overwintered beets. Bolting was reduced by more than half in the sprayed beets in this test. The sucrose percentage was increased significantly by maleic hydrazide, but no significant increase in beet tonnage or sugar yield resulted from the treatment.

## Discussion

In all tests, and with several varieties, maleic hydrazide exhibited a marked tendency to reduce and delay bolting. Bolting differences were not observed, however, unless maleic hydrazide was applied before or shortly after the appearance of seed stalks. After a period of 3 to 5 weeks from initiation of bolting secondary seed stalk formation seemed to occur and small spindly seed stalks developed.

Although it was possible to demonstrate significant increases in sucrose percentages, differences in sugar yield were not generally large enough to measure significant increases. Root yields were not consistently influenced by any treatment. As indicated in Table 3, considerable delay in harvest after bolting was initiated, tending to reduce sucrose percentages, offsetting any observed tonnage gains.

From the results of this series of experiments it would appear that any benefits from maleic hydrazide would be derived from its ability to delay bolting.

## Summary

Four experiments were conducted in the Sacramento ( San Joaquin, and Imperial Valleys of California on sugar beets planted in May or August for harvest the following spring. In the tests, foliar sprays of maleic hydrazide were applied by varying concentrations and at different dates with respect to time of harvest.

Maleic hydrazide delayed and reduced bolting and increased sucrose percentages in every case in which the material was applied before there was any visible evidence of bolting. In no case was root yield of beets significantly increased by any treatment. Generally speaking, yields of sugar per acre were not significantly affected by maleic hydrazide sprays.

### ACKNOWLEDGMENTS

Robert Ayers, Imperial County Farm Adviser, helped conduct the Imperial County Experiment. The maleic hydrazide used in these tests was supplied through the courtesy of the Naugatuck Division, U. S. Rubber Company.

## Literature Cited

(1) CHOUDHRI, R. S., and BHATNAGAR, V. B.
1953. Abs. Prevention of premature bolting in onions following maleic hydrazide treatment. Proc. Indian Academy of Sciences. B 37:14-21.

(2) JACKSON, H., and WITTWER, S. H.
1952. Abs. Some effects of maleic hydrazide on the reproductive development of celery plants. Paper presented Am. Soc. for Hort. Sci. Meeting, Ithaca, New York, Sept. 1952.

(3) MIKKELSEN, D. S., GRIFFITH, R. B., and RIRIE, D.
1952. Sugar beet response to maleic hydrazide treatment. Agron. Jour. 44:533-536.

(4) PETO, F. H., SMITH, W. G., and LOW, F. R.
1952. Effects of pre-harvest sprays of maleic hydrazide on sugar beets. Proc. Amer. Soc. Sugar Beet Tech. 101-107.

(5) PRICE, C., STEART, W. S. and ERICKSON, L. C.
1950. Some effects of plant growth regulators on bolting and other responses of sugar beets. Proc. Amer. Soc. Sugar Beet Tech. 131-136.

(6) STOUT, M.
1952. Two years' results evaluating effect of pre-harvest sprays of maleic hydrazide on respiration and spoilage of sugar beets. Proc. Amer. Soc. of Sugar Beet Tech. 95-100.

# ENTOMOLOGY
# AND
# PLANT PATHOLOGY

# Outbreaks of Beet Leafhoppers North and East of the Permanent Breeding Areas[1]

J. R. Douglass[2]

The occurrence of the beet leafhopper (*Circulifer tenellus* (Bak.)) in the sugar beet-producing areas of southwestern Kansas in 1953, together with the resulting curly top outbreak, has created considerable interest by the beet sugar industry in the leafhopper problem east of the Continental Divide.

The beet leafhopper was first recorded on sugar beets in 1895 by Gillett and Baker (1)[3] at Grand Junction, Colorado. The insect was originally described by Baker (2) in 1896 as *Thamnotettix tenellus* from a single female taken at Las Cruces, New Mexico, on *Sisymbrium*, a species of mustard; he noted that "It is quite a common insect in various parts of Colorado and will undoubtedly be found widely distributed in the West." In 1909 Ball (3) wrote that this leafhopper had been collected from near Denver, Colorado, and south along the edge of the mountains through New Mexico. He stated, "It was taken at Fort Collins and Lamar, Colorado, in 1901—in one case 100 miles north of its known habitat, on wild plants and in the other an equal distance east, but was rare in both situations."

In 1908 Townsend (4) wrote that George G. Hedgecock of the Bureau of Plant Industry found distinct cases of curly top in garden beets in Nebraska more than 20 years previously, which would have been before 1888. In discussing the distribution of curly top, referred to as "curly leaf," in 1917, Ball (5) gave the following occurrence in the Colorado-Nebraska-Kansas region:

> The Grand Island, Nebraska, factory started in 1890 and shipped beets from the northern Colorado districts until the Loveland factory was built in 1901. Hedgecock reports (in correspondence) that blight appeared in the Grand Island region in 1900 and again in 1901, in the latter year occurring over a wider area, but not so serious as at Grand Island the year previous.
>
> The factory at Rocky Ford was built in 1900 and the next year a small amount of curly-leaf appeared in the Arkansas Valley region. In 1903 the disease was quite serious in the whole southern Colorado section, extending down into Kansas.
>
> In 1908 curly-leaf started very early in the Arkansas Valley region and finally spread to include the entire Colorado-Nebraska-Kansas district, being very severe in the Arkansas Valley and lighter in the northern part of the state. The average production of the state was the lowest yet recorded.

In 1920 Lawson (6), in his study of the Cicadellidae of Kansas, reported the beet leafhopper from Clark County and remarked that it probably oc-

---

[1] Published with the approval of the director of the Idaho Agricultural Experiment Station as Research Paper No. 373.

[2] Entomologist, U. S. Department of Agriculture, Agricultural Research Service, Entomology Research Branch.

[3] Numbers in parentheses refer to literature cited.

curred in other southwestern counties. Severin and Severin (7) reported curly top at Belle Fourche, South Dakota, during the summer of 1926, but did not collect any beet leafhoppers. In 1927 Carter (8) reported the beet leafhopper and curly top from Billings, Bitterroot Valley, and Flathead Lake, Montana, and from Green River and Rock Springs, Wyoming.

Until 1953 the beet leafhopper had been reported only twice from east of the Mississippi River. DeLong (9) found it reproducing abundantly on sea purslane (*Sesuvium portulacastrum* L.) at Miami, Florida, in 1921. On October 6, 1936, he and Kadow (10) collected many specimens of this leafhopper from horseradish plants at Collinsville, Illinois, that were apparently infected with curly top. Since other leafhoppers were on the plants, the disease was not definitely identified but was later verified as curly top. On July 10, 1947, L. L. Dean of the Idaho Agricultural Experiment Station noted curly top in tomatoes at Lafayette, Indiana. These plants had been grown as seedlings in Moapa Valley, Nevada, and shipped to Indiana for transplanting. They could have been infected with curly top before shipping.

In 1953 Decker (11) reported that this leafhopper had been collected at several points in Illinios and that it was abundant in Madison County, and H. B. Petty reported collections in Champaign, Cook, Peoria, and St. Clair Counties. A. R. Downie reported finding curly top in sugar beets at Waseca, Minnesota, and Mason City, Iowa, in 1953, and the diseased plants were sent to N. J. Giddings (12), who confirmed their identification in his manuscript entitled "Curly Top Moves East." In 1953 R. M. Takeshita collected some sugar beet plants at Des Plains, Illinois. They were sent to Dr. Giddings, who found one to be infected with curly top. C. A. Lavis reported an occasional curly top-diseased beet in exploratory trial plantings in Douglass, Geary, Riley, and Wyandotte Counties in eastern Kansas.

## Breeding Areas

The only known breeding area of any size east of the Continental Divide is located in southern New Mexico and western Texas. Romney (13) concluded that the spring migrants from the permanent breeding areas in New Mexico and Texas infested the agricultural districts as far north as Alamosa and LaJunta, Colorado, and as far east as Hereford and Plainview, Texas. Figure 1 shows these breeding areas and other places east of the Continental Divide where beet leafhoppers or curly top have been reported.

## Spring Migrations

Glick (14), who over a 5-year period in Louisiana collected insects in the upper air with an airplane at different elevations and at different times of day and night, took the six-spotted leafhopper (*Macrosteles divisus* (Uhl.) = *fascifrons* (Stal.)). from 20 to 13,000 feet, 85 percent of them in the daytime. He found temperature to be the most important factor regulating the density of insects in the air at any given time, but that their distribution and dispersal is influenced by the air currents. The direction of the wind affects the migration of insects, and convection and turbulence play an

important role in determining the insect population in the upper air. As the air becomes rougher, a greater proportion of the insects are found at the higher elevations. When insects are in calm air and caught in strong ascending and horizontal currents of air, they are carried upwards.

We know that beet leafhoppers in flight come to the ground whenever the temperature becomes unfavorable. Those not landing on host plants will again take to the air when weather conditions become favorable. Leafhoppers are often forced down when they fly into air of low temperature.

The length of life of this insect without food is a factor in its long range migrations. Apparently airborne insects live longer than those near the ground. Harries and Douglass (15) found the average life of unfed

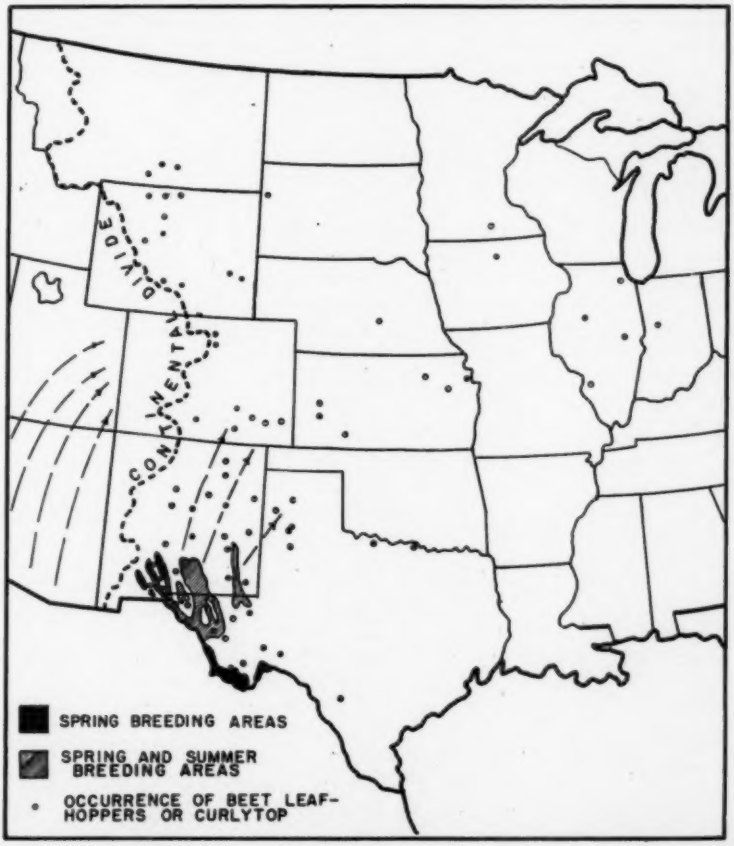


**Figure 1.—Breeding areas in New Mexico and western Texas and occurrence of beet leafhoppers or curly top east of the Continental Divide.**

females in the laboratory at approximately 50 percent relative humidity to be about 1 day at 90° F. and 3 days at 60°. Elton (16) reported that large numbers of the aphid *Dilachmus picea* (Panzer) were found on fresh snow after a strong wind at Nordaust Landet, Vest Spitsbergen, and concluded that they must have been carried by the wind from the spruce forests of northern Europe, at least 800 miles.

During years of large beet leafhopper populations combined with an early migration of the spring generation in southern Idaho, curly top has appeared in sugar beet areas east of Idaho. The prevailing winds across the Snake River plains of southern Idaho are from west to east, and since this leafhopper moves with the wind, the migration should be eastward. In 1926 a heavy movement of spring migrants occurred in southern Idaho between May 3 and 6, which is 21 days earlier than the average initial movement. In correspondence, Asa C. Maxson[4] wrote in 1940: "The first noticeable attack of curly top in Great Western territories occurred in the Wheatland, Wyoming, section in 1926. There has been no repetition of this outbreak in the Wheatland area since."

In 1934 a heavy spring migration of beet leafhoppers began in southern Idaho on April 27, the earliest on record. The first curly top epidemic occurred near Billings, Montana, in 1934. In 1941 a similar migration began on May 12, the earliest since 1934. Practically all the nonresistant sugar beets grown near Shell, Wyoming, in 1941 were affected by the disease late in the season. The leafhoppers which entered the area were able to produce a large population during the remainder of the season. Excessive precipitation fell in the Big Horn Basin that September and October, which was favorable for the early germination of the winter annual weed hosts. November and December were above normal in temperature, but January and February 1942 were below normal with an excess of precipitation. During this cold period the ground was covered with snow, which protected the leafhoppers from subzero temperatures, as shown by Douglass *et al.* (17).

March, April, and May were above normal in temperature and deficient in precipitation, which was favorable for leafhopper survival and for the early development of the spring generation. With the approach of spring, some of the overwintered leafhoppers moved into the beet fields, where they infected the young plants. These early cases of curly top served as infection centers from which the spring generation leafhoppers spread the disease to other plants. Low temperatures in June retarded curly top, but hot, dry weather in July and August stimulated its development. As the season advanced, curly top increased beyond expectations. There was some injury to sugar beets in the Big Horn Basin in 1943, but since that time this disease has not been of any economic importance.

### Beet Leafhoppers and Curly Top in Billings, Montana, and Big Horn Basin, Wyoming

Spring studies were made in the Billings area from 1936 to 1941 and again in 1951 to determine the abundance and distribution of the over-

[4] Formerly with the Great Western Sugar Company and author of "Insects and diseases of the sugar beet."

wintered beet leafhoppers. Their numbers varied in these years from 0 to 87 per 1,500 square-foot samples, which are low compared with the overwintered population in southern Idaho. These studies showed seven winter annuals on which this leafhopper can survive to produce a spring generation. Four of the most important summer hosts occur in the area. Although the number of spring and summer weed hosts is large, the acreages of these plants are small and often intermixed with nonhost grasses, which reduce their suitability for producing large numbers of leafhoppers.

The average annual precipitation for Billings is 14.38 inches, as compared with 9.81 at Twin Falls, Idaho. The normal precipitation at Billings for September and October is 2.62 inches, which is favorable for germination and fall growth of grasses. The April, May and June precipitation is 6.46 inches, which is favorable for the continued good growth of these grasses so that weed hosts on disturbed and overgrazed lands are replaced more rapidly than in southern Idaho, where the precipitation for the same period is 2.95 inches. This spring moisture promotes rank growth of annual weeds and thus reduces their suitability as hosts for the leafhoppers. The curly top injury to sugar beets at Billings persisted until 1941. The amount of injury caused by this disease varied from year to year and from locality to locality.

Studies conducted in the Big Horn Basin showed eight winter annuals which are spring hosts and five summer annuals which are hosts of this leafhopper. A total of 2, 45, 51, and 106 overwintered leafhoppers were found during the spring studies of 1943, 1944, 1945, and 1951. The number of square-foot samples taken ranged from 1,700 to 3,050 per year. Summer or fall studies made in 6 years showed low populations on summer weed hosts. The largest populations were found in a small patch of Russian thistle near Basin, Wyoming, on September 12, 1951, when 257 leafhoppers were recorded per square foot of weed host. Two small breeding areas were found near Basin and Shell in the Big Horn Basin, but no large host plant areas. The low annual rainfall is not favorable for the growth of the weed host plants in the desert area.

### Curly Top in Other Areas

Curly top was reported on sugar beets in the Arkansas Valley of Colorado in 1901, 1903, 1908, 1926, 1928-31, 1933, 1937, 1938, 1945, and 1950-53, and in the San Luis Valley in 1928-31, 1933, 1939, 1940, 1943, 1945, 1947, 1950, and 1953. On September 22-23, 1927, Carter (18) made eight collections of leafhoppers in the Arkansas Valley of Colorado in locations where large populations would be expected from the presence of suitable host plants. Only a few beet leafhoppers were found at six of the locations.

Although curly top had previously been reported from the Arkansas Valley of Kansas, it was not until 1953 that serious curly top injury to sugar beets occurred. From our present knowledge of the breeding areas, the spring migrants which infected sugar beets in Illinois, Iowa, Kansas and Minnesota evidently came from southern New Mexico and western Texas. Reports from New Mexico show serious curly top injury to tomatoes in that state in 1953, which indicates a large leafhopper population. The

occurrence of the beet leafhopper or curly top over such a wide area in the middle west indicated an abnormally high movement of leafhoppers from their southwestern breeding grounds in 1953, but yearly that repetitions of such movements would be unlikely.

The writer visited the sugar beet-producing area of Kansas from September 12 to 14, 1953, and, with John R. Latta of the Garden City Company and others, made a study of that company's Garden City and Scott City territories. Few beet leafhoppers were found on either sugar beets or Russian thistle, although the incidence of curly top was high in most of the fields examined. In bionomic studies of the beet leafhopper, Harries and Douglass (15) have shown that the length of life of the adults decreased to a few days at temperatures above 110° F., that egg-laying begins to decrease above 90° and ceases in about 1 day at 115°, that mortality in both the egg and nymphal stages increases at high temperatures, and that the development of this insect is retarded at temperatures above 95°. The low population of beet leafhoppers found in southwestern Kansas in 1953 may have been the result of a long hot, dry period in the summer.

In a study of beet leafhopper populations on summer hosts in the San Joaquin Valley of California, W. C. Cook (unpublished data) from 1930 to 1940 found that the populations on Russian thistle decreased considerably from June to September because of the high temperatures of July and August. Although high temperature was detrimental for the leafhopper, it was very favorable for the development of curly top.

Precipitation is the most important single limiting factor in controlling the distribution of the beet leafhopper. The total precipitation at Garden City from April 1 to August 31 was 12.36 inches, which was unfavorable for the reproduction and development of the beet leafhopper in that area.

Curly top occurred in sugar beets in western Texas in 1906, 1930, 1931, 1938-40, 1943, and 1945-53. In the fall of 1935 spinach near Crystal City was severely injured. A study indicated that the leafhoppers from the breeding areas of western Texas moved southeastward into that area with storm winds during the fall. In 1953 Richardson (19) reported widespread infestations in tomatoes and canning beets in Zavala County. In the same year Dobson (20) reported early in July that 20 percent of the tomato fields in Lee County, New Mexico, had been plowed up because of curly top and that the beet leafhopper was continuing to invade tomato fields in several counties.

Large populations of beet leafhoppers and serious losses to curly top-susceptible crops occurred in southcentral Idaho in 1919, 1921, 1924, 1926, 1930, 1931, 1934, 1935, 1937, 1941, and 1947, and probably would have occurred in 1950 and 1953 if the most productive spring breeding areas had not been sprayed. Injurious populations occurred in 13 of the 34 years, but only twice did they occur in two consecutive years, which were in the early 30's. Therefore, a serious curly top epidemic in one season does not mean that there will be another one the succeeding season.

Curly top is common in various areas in New Mexico where sugar beets are grown, but the percentage of plants infected has varied from

year to year and from locality to locality. The nearest known permanent breeding areas of the beet leafhopper at this writing are in southern New Mexico and western Texas. Since the prevailing summer winds across the Arkansas Valley blow from the south or southeast and those across New Mexico from the west, southwest and south, the leafhoppers which move into the sugar beet areas of southern Colorado and Texas must come from these breeding areas.

On the eastern slope of the Rocky Mountains in northern Colorado, a small amount of curly top has been observed nearly every year since 1910. Evidently the center of the infection is near La Porte, west of Fort Collins. Probably a study of that area would show a small leafhopper-breeding area. In conversation Asa C. Maxson in 1942 stated that he believed that there was a small local breeding area in one of the canyons near Fort Collins. For several years there has been a light curly top infection near Wheatland, Wyoming, and there may be a small leafhopper-breeding area nearby.

A large spring population of the leafhoppers was produced in southern Idaho in 1937, but the spring movement was late. Early in September Russian-thistle patches growing near U. S. Highway 30 between Lava Hot Springs, Idaho, and Laramie, Wyoming, were sampled for leafhoppers. The first five samples were taken approximately every 12.5 miles and the remaining samples every 20 miles. Beet leafhoppers were found at every collecting point except just west of Laramie. The largest population in Wyoming, which averaged 2.8 leafhoppers per square foot of weed host, was found near Rock Springs. The population was low throughout eastern Idaho and southern Wyoming.

The beet leafhopper weed-host complex has changed in favor of the insect in many areas during the last 30 years, and there is more than a bare possibility that this leafhopper is becoming acclimated to new areas. Therefore, we must be prepared for major changes over a longer period of years.

## Summary

The occurrence of beet leafhoppers (*Circulifer tenellus* (Bak.)) in the sugar beet producing areas of southwestern Kansas in 1953, with the resulting curly top outbreak, has created considerable interest by the beet sugar industry in the leafhopper problem east of the Continental Divide. From our present knowledge of their breeding areas, the leafhoppers which moved into the Kansas area were migrants from southern New Mexico and western Texas.

Outbreaks of economic importance also occurred at Billings, Montana, in 1934 and in the Big Horn Basin, Wyoming, in 1941. These areas were infested during the spring by long range migrations of this leafhopper from, apparently, the breeding areas of southern Idaho.

The occurrence of this insect or of curly top in areas far removed from the permanent breeding grounds shows that the beet leafhopper is a migratory insect which occasionally extends its normal range into areas where it cannot survive because of the climate. The occurrence of curly top out of its normal economic range during a certain season does not indicate that it will be followed by another epidemic during the succeeding one.

**ACKNOWLEDGMENT**

The author is grateful to P. B. Smith, R. L. Kimmons, and W. C. McCarty of the Great Western Sugar Company; C. W. Doxtator and Andrew R. Downie of the American Crystal Sugar Company; C. A. Lavis and C. E. Cormany of the Holly Sugar Corporation; H. B. Petty of the Illinois State Natural History Survey; R. M. Takeshita of the Illinois Agricultural Experiment Station; and N. J. Giddings and John O. Gaskill of the Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture, for information on the occurrence of this insect or curly top in the various sugar beet-producing areas east of the Continental Divide, and to H. C. Hallock and W. E. Peay of the Entomology Research Branch, Agricultural Research Service, for assistance in compiling the data.

## Literature Cited

(1) GILLETTE, C. P., and BAKER, C. F.
1895. A preliminary list of the Hemiptera of Colorado. Colo. Agr. Expt. Sta. Bul. 31: 100.

(2) BAKER, C. F.
1896. New Homoptera received from the New Mexico Agricultural Experiment Station 11. Psyche 7, Suppl. 1: 24-26.

(3) BALL, E. D.
1909. The leafhoppers of the sugar beet and their relation to "the curly leaf" condition. U. S. Dept. Agr. Bur. Ent. Bul. 66, part 4: 33-52.

(4) TOWNSEND, C. O.
1908. Curly top, a disease of the sugar beet. U. S. Dept. Agr. Bur. Plant Indus. Bul. 122, 37 pp.

(5) BALL, E. D.
1917. The beet leafhopper and the curly leaf disease that it transmits. Utah Agr. Expt. Sta. Bul. 155: 1-56.

(6) LAWSON, P. B.
1920. The Cicadellidae of Kansas. Kans. Univ. Sci. Bul. 12: 180.

(7) SEVERIN, H. H. P., and SEVERIN, H. C.
1927. Curly top of sugar beets in South Dakota. Jour. Econ. Ent. 20: 586-588.

(8) CARTER, WALTER.
1927. Extension of the known range of *Eutettix tenellus* Baker and curly top of sugar beets. Jour. Econ. Ent. 20: 714-717.

(9) DELONG, D. M.
1925. The occurrence of the beet leafhopper, *Eutettix tenellus* Baker, in the eastern U. S. Jour. Econ. Ent. 18: 637-638.

(10) DELONG, D. M., and KADOW, K. J.
1937. Sugar beet leafhopper appears in Illinois. Jour. Econ. Ent. 30: 210.

(11) DECKER, G. C.
1953. Beet leafhopper *(Circulifer tenellus)*—Illinois. U. S. Bur. Ent. and Plant Quar., Coop. Econ. Insect Rpt. 3 (37): 674.

(12) GIDDINGS, N. J.
1954. Curly top moves east. Proc. Amer. Soc. Sugar Beet Tech. ——

(13) ROMNEY, V. E.
1939. Breeding areas and economic distribution of the beet leafhopper in New Mexico, southern Colorado, and western Texas. U. S. Dept. Agr. Cir. 518, 15 pp.

(14) GLICK, P. A.
1939. The distribution of insects, spiders, and mites in the air. U. S. Dept. Agr. Tech. Bul. 673, 151 pp.

(15) HARRIES, F. H., and DOUGLASS, J. R.
1948. Bionomic studies of the beet leafhopper. Ecol. Monog. 18: 45-79.

(16) ELTON, C. S.
1925. The dispersal of insects to Spitzbergen. London Ent. Soc. Trans. 1925: 289-299.

(17) DOUGLASS, J. R., ROMNEY, V. E., and HALLOCK, H. C.
1950. Survival of the beet leafhopper in southern Idaho during the severe winter of 1948-49. Proc. Amer. Soc. Sugar Beet Tech. 1950: 494-498.

(18) CARTER, WALTER.
1930. Ecological studies of the beet leafhopper. U. S. Dept. Agr. Tech. Bul. 206, 115 pp.

(19) RICHARDSON, B. H.
1953. Beet leafhopper (*Circulifer tenellus*)—Texas. U. S. Bur. Ent. and Plant Quar. Coop. Econ. Insect Rpt. 3 (22): 396.

(20) DOBSON, RICHARD C.
1953. Beet leafhopper (*Circulifer tenellus*)—New Mexico. U. S. Bur. Ent. and Plant Quar. Coop. Econ. Insect Rpt. 3 (28): 519, and 3 (29): 536.

# Curly Top Moves East

N. J. GIDDINGS[1]

It is a commonly accepted fact that sugar beet curly top is likely to cause serious damage in many areas west of the Rocky Mountains and we know that it is occasionally found east of the mountains. The vector, *Circulifer tenellus* (Baker), has been reported from Florida and the West Indies (6)[2] and from Illinois (4), but no proved case of curly top injury to plants has been found farther east than Jacksonville, Texas, previous to 1953.

During the summer and early fall of 1953 shipments of beet leafhoppers were received from Dr. H. H. Thornberry of the University of Illinois and culy top virus was obtained from some of the leafhoppers in each lot. The collections were made in Madison, St. Clair, Peoria and Champaign counties. Some sugar beets from Cook County, north of Chicago, were also sent for testing and curly top virus was obtained from one of them. This proves that curly top was present more than 400 miles farther east than shown by any previous record.

Curly top diseased beets were also received at Riverside from Mason City, Iowa, and Waseca, Minnesota. The virus obtained from these beets and that obtained from the Illinois leafhoppers and beets appear to be mild to intermediate in virulence toward sugar beets according to our present standards. Some of those classed as intermediate now might have been placed in the highly virulent group five years ago, as much more virulent strains have come to light since then.

During September, 1953, there were reports of curly top damage in southeastern Colorado and southwestern Kansas. A visit to those areas in early October revealed an appreciable amount of curly top in the Swink-LaJunta area of Colorado but the amount of actual damage appeared to be relatively small. In the fields visited it was estimated that about 5 percent of the plants showed obvious curly top symptoms.

In the Garden City-Scott City area of Kansas there was evidence of extreme damage similar to that which used to occur in Idaho, Utah and California before curly top-resistant sugar beet varieties were available. Field men reported that some growers were harvesting crops which yielded 4 to 5 tons of beets per acre. There was clear evidence that virulent strains of curly top virus were present but there were undoubtedly other factors involved. Curly top injures or kills the tiny feeder roots of the beets (5) just about as soon as any visible symptoms appear on the leaves and water shortages result in serious injury to such beets much sooner than to beets with a normal root system. Some fields had very poor stands and there was evidence that large beets had died. We have no practical way to determine whether curly top was a major factor in the death of these beets but it may well have been. The injured feeder roots not only require a better supply

---

[1] Collaborator (formerly Senior Pathologist), U. S. Department of Agriculture, Riverside, California.

[2] Numbers in parentheses refer to literature cited.

of available water but are also a convenient place for the entry of soil fungi which induce decay. It is rather unusual for relatively large sugar beet plants to be killed by curly top unless some secondary factor is involved. There was definite evidence of some other virus diseases in the area but it is quite certain that they were relatively unimportant. It is also possible that the curly top virus was present at an earlier date than was suspected as some of the virus strains found there induce leaf symptoms which are quite different from our "classical" idea of that disease.

Beet samples were taken from both the Kansas and the Colorado areas and have been carefully tested at the Riverside Field Station of the U. S.

**Figure 1. A and B are plants in sugar beet field near Garden City, Kan. A shows lateral curling and dwarfing similar to plants infected by curly top virus strains 5, 6, 10 and 12. B, general distortion with pronounced crinkling of the younger leaves as induced by strains 1, 3, and 11.**

**C, D, E and F are greenhouse plants infected by curly top virus obtained from sugar beets collected in Kansas and Colorado. C shows symptoms on beet SL 842 characteristic of strains 1, 3 or 11. D, symptoms on beet SL 68 characteristic of strain 11. E, symptoms on beet SL 842 characteristic of strains 5 or 6. F, symptoms on beet SL 842 characteristic of strain 10. H, healthy check of beet SL 842.**

Department of Agriculture. Symptoms suggestive of other virus diseases were present on some of the beets selected for testing but curly top virus was obtained from every beet. At least one other virus was present in some of these plants and Dr. C. W. Bennett of this station is giving them some study. The curly top virus strains obtained from the beets have been tested on susceptible and resistant sugar beets and on Turkish tobacco. Some have also been tested on tomato. Many, and possibly each, of the beets had infection by more than one strain of the curly top virus. Results at the time of writing clearly show 3 virus strains in the Swink-LaJunta area and 4 strains in the Garden City-Scott City area. There may well be other strains present. One strain from each area would be classed as intermediate in virulence and the others range from highly virulent to extremely virulent. One strain, or strain complex, from each area appears to be equal in virulence to strain 11 (3), the most virulent curly top strain yet encountered. Three others appear to be strains 1, 3 and 10 (1, 2). Figures 1A and B show typical symptoms induced by two strains.

The explanation of this disastrous curly top outbreak remains to be determined. It might be due to an unusually great influx of leafhoppers from western Texas and from New Mexico. It is quite possible that there have been great changes in breeding areas and/or host plants in this general region. It is certain that the beet leafhoppers entering the southwestern Kansas and southeastern Colorado areas were carrying curly top virus strains which might be disastrous to the beet sugar industry there. It is clearly evident that growers east of the Rocky Mountains must seek sugar beet varieties whcih are resistant to curly top.

## Literature Cited

(1) GIDDINGS, N. J.
1937. A greenhouse method for testing resistance to curly top in sugar beets. Phytopathology 27:773-779.

(2) GIDDINGS, N. J.
1938. Studies of selected strains of curly top virus. Jour. Agr. Res. (U. S.) 56:883-894.

(3) GIDDINGS, N. J.
1954. Two recently isolated strains of the curly top virus. Phytopathology (in press).

(4) KADOW, K. J., and ANDERSON, H. W.
1936. Brittle root of horseradish in Illinois. Plant Disease Reporter 20:288.

(5) LACKEY, C. F.
1947. Effect of curly-top virus strains on extent of injury in root tips of susceptible and resistant sugar beets. Phytopathology 37:844 (Abstract).

(6) OMAN, P. W.
1949. The nearctic leafhoppers, a generic classification and check list.

# Relative Curly-Top Resistance of Sugar Beet Varieties in the Seedling Stage

N. J. GIDDINGS[1]

It has long been recognized that early planted sugar beets were less likely to suffer serious injury from curly top than later plantings. The reason is that the older plants are much more resistant at the time of leafhopper invasion (1, 6, 7)[2] Also, it often has been assumed and stated that curly top-resistant varieties of sugar beet were "susceptible" when young, thus implying that the resistant beets are injured as much as susceptible varieties if the young plants are infected.

Seedling plants of resistant varieties do show much greater resistance to both infection and injury than comparable plants of susceptible varieties. Evidence published in 1937 (2) showed that seedlings of U. S. 1, a beet of relatively low resistance, were more resistant to infection, slower in developing symptoms and less severely injured than comparable plants of the commonly used commercial beet varieties. These tests included data from several experiments and more than 2,300 plants. All plants were in the cotyledon or very young two-leaf stage when inoculated and one viruliferous leafhopper was used on each plant. These plants were grown under environmental conditions which were as nearly comparable as anyone might reasonably wish and the results showed the same trend in every experiment. The same publication gave similar, but less voluminous, evidence concerning some other curly top-resistant beets, including selections from U. S. 1.

Some detailed evidence concerning resistance to infection and to injury in the cotyledon or young two-leaf stage was published in 1938 (3). Data from field experiments of 1939 and 1941 were published in 1942 (4). This dealt with young plants of the beet varieties Old Type, U. S. 22 and Improved U. S. 22. The plants were inoculated immediately after thinning. The results were similar to those reported earlier but much more pronounced in the case of Improved U. S. 22. Some additional evidence from greenhouse experiments was published in 1944 (5).

The data used in all the above mentioned work were checked statistically and found to be highly significant.

The author believes that there has been some misunderstanding concerning the use of the word "susceptible." Young plants of any sugar beet variety which has been tested may be infected with curly top virus by the use of sufficient numbers of leafhoppers carrying the proper strain or strains of virus, but that is relatively unimportant if the plant is not seriously injured, recovers and continues to make good growth. The important factor is susceptibility or resistance to injury by the curly top virus rather than susceptibility to infection.

---

[1] Collaborator (formerly Senior Pathologist), U. S. Department of Agriculture, Riverside, California.

[2] Numbers in parentheses refer to literature cited.

During the last few years we have had to deal with newly discovered and more highly virulent strains of the curly top virus. Some data from recent experiments are given in Tables 1 and 2.

**Table 1.—Curly Top Resistance of Sugar Beet Varieties Infected in Cotyledon or Very Young Two-Leaf Stage. Results 6 Weeks After Inoculation.**

| Beet Variety | A. Plants Infected with Virus Strains 1 or 11[1] | | | | B. Data for 4 Groups of Plants Inoculated with Virus Strains 1, 3, 11 or 12[2] | |
|---|---|---|---|---|---|---|
| | Strain 1 | | Strain 11 | | | |
| | Average Severity | Plants Dead | Average Severity | Plants Dead | Average Severity | Plants Dead |
| | Grade | % | Grade | % | Grade | % |
| SL 842 | 4.8 | 42 | 4.7 | 89 | | |
| SL 1-300(OT) | 3.8 | 25 | 4.8 | 70 | 3.4 | 30 |
| SL 175 | 1.8 | 4 | 4.3 | 54 | 2.6 | 12 |
| SL 824 | 1.7 | 2 | 4.4 | 16 | 2.7 | 6 |
| SL 96(22/3) | 1.6 | 0 | 4.2 | 27 | 2.6 | 10 |
| SL 92M1 | 1.3 | 0 | 3.6 | 7 | 2.5 | 10 |
| SL 92 | 1.4 | 0 | 3.5 | 0 | 2.3 | 0 |

[1] Data included in Part A covers three experiments with approximately 100 plants for each beet variety and each virus strain.
[2] Data in Part B includes approximately 80 plants of each beet variety, Except SL 92M1, which had only 28 plants. Averages include the 4 virus strains for each beet variety.

The extreme virulence of virus strain 11 is clearly evidenced in Section A of Table 1 by the severity of symptoms and the percent of plants killed within 6 weeks after inoculation. Cotyledon and very young two-leaf stage plants of beet varieties S. L. 92M1 and 92, curly top-resistant selections from 22/3, are outstanding in resistance to injury from virus strain 11. This fact is more evident in the percent of plants killed than in the degree of severity.

Figure 1 shows typical results obtained on plants of beet varieties S. L. 1-300 (Old Type), and S. L. 92 infected by curly top virus strains 11, 1 and 3 respectively.

It is fortunate that a sugar beet field is very rarely apt to have widespread infection by curly top virus strain 11, or one of similar virulence, while the plants are young. This is because such highly virulent strains are likely to cause extreme dwarfing or death of wild hosts and so become somewhat self-limiting in winter and spring plant host areas. The data given under Section A Virus Strain 1 or under Section B of Table 1 are more likely to be what one might expect under field conditions than that given under Virus Strain 11 of Section A.

Table 2 gives evidence of the increased retsistance of young plants during an 8-day period of growth. Only approximately 20 plants were included in the test of each beet variety with each virus strain on each inoculation date but the tendency toward increased resistance is shown in the resistant varieties, particularly in S. L. 92M1 and S. L. 82.

Resistance to curly top infection and resistance to injury increases with age in all sugar beet varieties which have been tested. The increase in resistance is generally more rapid in varieties which are listed as resistant than

**Table 2.—Increase in Curly Top Resistance of Young Sugar Beet Seedlings During an 8-Day Period of Growth in Greenhouse.[1]**

| Beet Variety | Curly Top Virus Strain 1 | | | | Curly Top Virus Strain 11 | | | |
|---|---|---|---|---|---|---|---|---|
| | Average Severity Inoculated October | | Plants Dead Inoculated October | | Average Severity Inoculated October | | Plans Dead Inoculated October | |
| | 5th | 13th | 5th | 13th | 5th | 13th | 5th | 13th |
| | Grade | Grade | % | % | Grade | Grade | % | % |
| SL 842 | 4.7 | 5.0 | 50 | 27 | 4.7 | 4.6 | 84 | 87 |
| SL 1-300(OT) | 4.4 | 4.4 | 47 | 13 | 4.8 | 4.9 | 82 | 65 |
| SL 175 | 2.0 | 2.1 | 12 | 0 | 4.6 | 4.1 | 71 | 50 |
| SL 824 | 1.8 | 1.2 | 0 | 0 | 4.7 | 4.2 | 24 | 13 |
| SL 96(22/3) | 1.6 | 1.3 | 0 | 0 | 4.6 | 4.5 | 32 | 36 |
| SL 92M1 | 1.3 | 1.1 | 0 | 0 | 4.1 | 3.2 | 5 | 0 |
| SL 92 | 1.5 | 1.2 | 0 | 0 | 3.9 | 3.5 | 0 | 0 |

[1] Plants inoculated October 5 were strictly in cotyledon stage and those inoculated October 13 were in very young two-leaf stage.

**Figure 1. Sugar beet plants six weeks after inoculation with curly top virus strains. Top row is variety S. L. 1-300 (Old Type). Bottom row is S. L. 92. Plants in pots at left infected by virus strain 11, in middle pots by strain 1 and in pots at right by strain 3.**

in those more susceptible. There is abundant evidence that resistant sugar beet varieties possess a great measure of that quality of resistance to both infection and to injury while the seedlings are still in the cotyledon and very young two-leaf stage. Comments concerning curly top-resistant varieties should avoid the implication that they are in the same class as the susceptible varieties during their early growth.

## Literature Cited

(1) CARSNER, EUBANKS and STAHL, C. F.
1924. Studies on curly top disease of the sugar beet. Jour. Agr. Res. Res. 28:313-314.

(2) GIDDINGS, N. J.
1937. A greenhouse method for testing resistance to curly top in sugar beet. Phytopathology 27:773-779.

(3) GIDDINGS, N. J.
1938. Studies of selected strains of curly top virus. Jour. Agr. Res. 56:883-894.

(4) GIDDINGS, N. J.
1942. Age of plants as a factor in resistance to curly top of sugar beets. Amer. Soc. Sugar Beet Tech. Pg. 452-459.

(5) GIDDINGS, N. J.
1944. Additional strains of the sugar beet curly top virus. Jour. Agr. Res. 69:149-157.

(6) SKUDERNA, A. W., CORMANY, C. E. and HURST, L. A.
1933. Effects of time of planting and of fertilizer mixtures on the curly top-resistant sugar beet variety U. S. No. 1 in Idaho. U. S. Dept. Agr. Circ. 273.

(7) WALLACE, J. M. and MURPHY, ALBERT M.
1938. Studies on the epidemiology of curly top in souther Idaho with special reference to sugar beets and weed hosts of the vector, *Eutettix tenellus*. U. S. Dept. Agr. Tech. Bul. 624.

# Beet Leafhopper Outlook Statements[1]

HOWARD E. DORST[2]

The beet leafhopper, *Circulifer tenellus* (Baker), is the vector of curly top, a disease of sugar beets, tomatoes, beans and cantaloupe. This disease varies in intensity from year to year and frequently causes a sharp reduction in yields of these crops. The leafhopper migrates from adjacent and distant semi-desert flora to the agricultural areas of Utah, western Colorado, southern Nevada, central Arizona and southeastern California.

Ecological studies of the leafhopper, made by the author in the desert breeding areas prior to its migration, included the determination of the relationship of this insect to certain plants and the factors which influence its distribution. Evaluation of such factors as climatic conditions and numerical abundance of the insect has provided a basis for the research worker to anticipate the time and intensity of the yearly movement. The information obtained each year has been released in the form of leafhopper outlook statements prior to the planting date of susceptible crops in the agricultural area. Information from these statements can be used to govern the planting of varieties of sugar beets most resistant to curly top when the outlook is for a year high in leafhopper numbers. The more susceptible varieties of sugar beets can be planted in years of low leafhopper numbers.

Ecological studies of the beet leafhopper in its winter, spring and summer breeding areas to determine the source of the movement into Sevier Valley, Utah, were initiated in the late 1920's. The desert areas between St. George, Utah, and Las Vegas, Nevada, were first studied; later other workers collected data in areas near Phoenix, Arizona (5),[3] Needles, California, and Las Vegas, Nevada. Except for the period from 1936 to 1942, data for each year since the beginning of the study have been accumulated on the conditions occurring in these areas during late winter and early spring months and corresponding spring and summer leafhopper population data have been taken in cultivated districts of Utah and western Colorado.

The beet leafhopper multiplies in great numbers in the winter and spring months when certain plants are present in the breeding areas. The kind of plants present, the time of their germination, and their distribution all greatly influence the degree of increase in the leafhopper population. The quantity of precipitation and time of its occurrence are directly related to the germination and sustenance of the host plants. High temperatures which follow precipitation may reduce its effectiveness because of the evaporation and loss of moisture. Winter temperatures in the southern breeding areas are not low enough to cause leafhopper mortality.

Normally little precipitation occurs in the southern breeding areas in early summer, therefore few annuals are present and the leafhopper popula-

---

[1] This work was carried out cooperatively by the U. S. Department of Agriculture and the Utah Agricultural Experiment Station.

[2] Entomologist, Entomology Research Branch, Agricultural Research Service, USDA.

[3] Numbers in parentheses refer to literature cited.

tion is much reduced. Summer breeding areas receive late winter, spring and summer precipitation, which germinates and sustains Russian thistle, *Salsola kali,* with one or more other plants. Large summer breeding areas covered by Russian thistle have been studied in the Escalante Desert of southern Utah, in the Wolf Hole district of northwestern Arizona and in the Douglas district of southeastern Arizona. In southern Arizona (5) precipitation which occurs between July and September may cause such plants as chinchweed, *Pectis papposa, Tridestromia lanuginosa,* and several other annuals to germinate which serve as host plants for the leafhopper. The leafhopper population increases to large numbers on these summer host plants. In the fall, as the summer host plants dry, the leafhopper is forced to seek other food.

If precipitation has occurred in the late summer or fall in the winter and spring breeding grounds of the beet leafhopper, germination of the winter host plants may take place prior to the return movement of leafhoppers from the summer breeding areas. The more common winter host plants are alfileria, *Erodium cicutarium;* annual plantain, *Plantago insularis;* peppergrass, *Lepidium densiflorum;* spectacle-pod mustard, *Dithyrea wislizeni;* bladder-pod mustard, *Lesquerella fendleri;* roadside mustard, *Sisymbrium irio,* and borage, *Cryptantha barbigera.* If one or more of these species of plants germinates over a large area and is present when the fall movement occurs, the leafhopper is provided adequate food. However, if precipitation fails, and there is a dearth of winter annuals, the leafhopper is forced to feed on such undesirable plants as creosote-bush, *Covillea tridentata,* or some other perennial plants. Under these circumstances, a high mortality of the insect occurs within 30 to 60 days because these perennials are not favorable food, and act only as carryover host plants.

The percentage of leafhoppers which carries the curly top virus varies considerably from year to year. The reason for this variation is not well known. Certain weed host plants which leafhoppers feed upon are naturally infected with the virus disease. Nevertheless, the percentage of viruliferous hoppers collected from specific host plants varies from year to year. The percentage of viruliferous leafhoppers in the migration from the winter desert breeding grounds to the agricultural area heavily influences the amount of damage incurred.

In northwestern Mexico, southern Arizona and southeastern California, a generation of leafhoppers may be produced by January or early February. By this time in many years the winter-germinated annuals have matured, and the leafhopper has been forced to move further north for food.

If favorable host plant conditions are present, a generation of winged leafhoppers may mature in the Phoenix, Arizona, and the Blythe and Indio, California, areas by March. Movement from the south may populate the host plants in this area in February. These leafhoppers may produce a second generation by April. Cultivated crops susceptible to the curly top disease in adjacent territory and northward may be populated by the leafhoppers during February, March and even April.

If favorable host plant conditions are present, a generation of leafhoppers may mature in the Barstow-Needles, California, area by April. Leaf-

hoppers from further south could have populated this area in February and March; and if plants are favorable, these populations would be produced in late April or early May.

In the St. George, Utah; Littlefield, Arizona; Kingman, Arizona, and Las Vegas, Nevada, sectors, a generation of leafhoppers may mature by late April or early May. Leafhoppers further south may populate the annuals and continue to reproduce into mid-May.

Under favorable host plant conditions there may be an accumulation of leafhoppers by additional generations which may prolong the leafhopper movement to the cultivated districts of northern Utah and western Colorado from late March and April to mid-May.

The species, abundance and distribution of host plants during the winter and spring months greatly influence the magnitude of the movement of beet leafhoppers to cultivated districts. Since certain host plants are more favorable for the leafhopper and thereby permit the production of larger broods than others, this situation must be evaluated each year by plant and insect surveys. The brood of leafhoppers produced on spectacled-pod mustard and peppergrass mustard is largest, but the acreage of these plants varies greatly from year to year. Plantain produces a larger brood than alfileria. The acreage of host plants is important in that it greatly influences the total number of leafhoppers produced in a given season for the migration.

In recent years the acreage of host plants has been determined over the vast desert breeding area by recording their absence or presence at 10-mile stops. If host plants are present they are classified as wide spread, spotted, or confined to washes and roadsides only. Plant cover at these stops has been determined by recording the number of steps in which plants touch the toe of the shoe in 50 conventional strides. Normally, a plant cover which completely shades the soil surface is not as favorable for leafhopper breeding as a sparser stand. The condition and stage of maturity of the plants have been classified as seedling, flowering, succulent, hardening or dead. The unit leafhopper populations have been determined at 50 randomized square foot samples at each stop where host plants were present. The percentage of viruliferous leafhoppers and virulence of the virus strain have been determined by inoculating individual curly top-susceptible beets in the cotyledon stage with single leafhoppers collected from different host plants in the desert breeding area. The percentage of the inoculated beets which develop curly top symptoms and the virulence of the attack are determined for the viruliferous reading.

The beet leafhopper population, host plant distribution, percentage of viruliferous leafhoppers in desert breeding areas, and percentage of tomato plants infected by curly top in northern Utah and western Colorado from 1946 to 1953 are shown in Table 1.

The highest average leafhopper population in February in the desert breeding area of southern Utah, southern Nevada, southeastern California, southern Arizona and western Arizona since the studies began was recorded

**Table 1.—Beet Leafhopper Population and Conditions Observed in Desert Breeding Areas from 1946-1953.**

| Year | Regular 10 mile stops | Stops with widespread host distribution | Average beet leafhopper population in desert per square foot | Leafhoppers carrying virus | Tomato plants infected with curly top | |
|---|---|---|---|---|---|---|
| | | | | | Western Colorado | Utah |
| | number | percent | number | percent | percent | percent |
| 1946 | 54 | 17 | 0.049 | 8.0 | — | 2.0 |
| 1947 | 72 | 54 | 0.028 | — | — | 8.0 |
| 1948 | 206 | 28 | 0.044 | 4.0 | 20.0 | 3.0 |
| 1949 | 246 | 32 | 0.013 | — | 0.1 | 0.1 |
| 1950 | 248 | 16 | 0.016 | 0 | 7.0 | 0.8 |
| 1951 | 200 | 10 | 0.015 | 2.0 | 0.6 | 0.5 |
| 1952 | 217 | 46 | 0.087 | 10.4 | 45.0 | 12.0 |
| 1953 | 217 | 25 | 0.04 | 14.5 | 8.0 | 6.0 |

in 1952. In that year 46 percent of the 10-mile stops where plants were present showed that widespread distribution of hosts was common to the area. In northern Utah, 12 percent curly top damage to tomatoes was recorded, with 45 percent damage to tomatoes in western Colorado; sugar beets in southern Utah and western Colorado showed from 40 to 50 percent obvious curly top. In 1951, by contrast, the average leafhopper population in the desert was 0.015 per square foot and only 10 percent of the stops showed widespread distribution of host plants. Curly top damage to tomatoes that year was absent. Damage to sugar beets was also negligible.

Host plant conditions in the desert breeding area vary considerably over a period of years. Portions of the desert which produced good stands of host plants in the St. George-Littlefield-Las Vegas areas in the late 1920's and early 1930's have not been productive more recently. When favorable precipitation occurs, host plants are found in other portions of the desert and different species are present from those observed in earlier studies. Different host distribution also has been noted in the Phoenix-Blythe-Needles-Las Vegas areas than that recorded in the early 1930's. The time and quantity of precipitation apparently determine the species of host plants which may germinate.

The winter desert breeding area is divided by the Colorado River. The leafhopper movement from the east side of the river may be carried to the eastern part of Utah and western Colorado. On the other hand, leafhoppers which mature on the west side of the Colorado River may be carried to northern Utah up the Virgin and Sevier River basins. Wind directions at the time of the leafhopper movement probably influence the distribution to the different agricultural areas. The long distance movements (2) to the cultivated areas of northern Utah have been detected as early as late March, but in average years most of the movement in Utah and western Colorado has occurred by May 15.

Even though the source of leafhoppers which migrate to the cultivated areas of northern Utah and western Colorado is identical, the magnitude of the leafhopper migration to western Colorado may be greater. Large

populations often are produced in the portion of the breeding area east of the Colorado River, and the Colorado River basin provides an avenue for the leafhoppers to move to eastern Utah and western Colorado. In 1948, 20 percent curly top was recorded on tomatoes in western Colorado but only 3 percent in northern Utah. In 1952, the incidence of curly top on tomatoes in western Colorado was 45 percent, in contrast to 12 percent in northern Utah.

During some years in northern (4) and eastern Utah and western Colorado, local breeding areas produce leafhoppers which migrate to the adjacent cultivated districts. Precipitation in the fall which germinates such annuals as alfileria, *Erodium cicutarium;* African mustard, *Malcolmia africana* and blister cress, *Erysimum repandum,* is favorable for winter survival of this insect. If a large population of leafhoppers enters the winter under favorable host plant conditions, winter temperatures may reduce their numbers to insignificance. The leafhopper movement from these areas which occurs in June was in the past of some consequence, but in recent years has become less important because grasses have replaced the former weeds.

Some breeding areas in northern Utah adjacent to Great Salt Lake and Utah Lake, and areas in eastern Utah and western Colorado may be populated by the long distance migrants in the spring. Under favorable host plant conditions a brood of leafhoppers may be produced before movement to the adjacent cultivated areas. These movements usually occur in early June after beets have reached the 10- to 12-leaf stage; however, the leafhopper may infect susceptible crops such as tomatoes, cantaloupe and beans. The higher incidence of curly top on tomatoes in western Colorado in 1952 in comparison with northern Utah was in part the result of a local movement of leafhoppers from eastern Utah.

Resistant strains of sugar beets have provided major protection against the inroads of curly top transmitted by the beet leafhopper. Maximum resistance to curly top is reached after the sugar beets reach the 10- to 12-leaf stage of development (3). In 1940 (1), 1952 and 1953 beet leafhopper populations grreater than 1 per square foot of beet row occurred on sugar beets while in the cotyledon to 8-leaf stage of development. Under these circumstances, 40 to 80 percent obvious curly top was observed and the yield of sugar beets was considerably reduced.

## Summary

The beet leafhopper, *Circulifer tenellus* (Baker), is a pest of sugar beets, tomatoes, beans and cantaloupe in the intermountain area. The leafhopper population varies in intensity from year to year, frequently causing sharp reduction in yields of susceptible crops. This pest migrates to the cultivated districts of Utah, western Colorado, southern Nevada, central Arizona and southestern California, from semi-desert breeding areas in southern Utah, southern Nevada, southeastern California, western Arizona and southern Arizona.

Studies of the leafhopper population in semi-desert breeding areas and its corresponding damage to susceptible crops in the cultivated districts

were initiated in the late 1920's and have been continued each year except during the period 1936-1942. The data collected in these studies and their evaluation have provided a basis from which the research worker can estimate the anticipated magnitude of the beet leafhopper migration and expected damage to cultivated crops each spring.

By using this information, the sugar beet industry may determine the selection of resistant strains of sugar beets which will give the best returns in line with the anticipated magnitude of the leafhopper movement.

## Literature Cited

(1) DOUGLAS, J. R., DORST, H. E., and PEAY, W. E.
1946. Beet leafhopper population in southern Idaho and northern Utah during the seasons of 1940 and 1941. Amer. Soc. Sugar Beet Tech. Proc. pp. 289-297.

(2) DORST, H. E., and DAVIS, E. W.
1938. Tracing long-distance movements of beet leafhopper in the desert. Jour. of Econ. Ent. 30 (6) 948-954.

(3) GIDDINGS, N. J.
1942. Age of plants as a factor in resistance to curly top of sugar beets. Amer. Soc. Sugar Beet Tech. Proc. pp. 452-459.

(4) KNOWLTON, G. F.
1932. The beet leafhopper in northern Utah. Utah Agr. Exp. Bul. 234, 64 pp.

(5) ROMNEY, VAN E.
1943. The beet leafhopper and its control on beets grown for seed in Arizona and New Mexico. U. S. Dept. Agr. Tech. Bul. 855, 24 pp.

# Chromatography as a Method of Attack on the Problem of the Chemical Nature of Resistance of Sugar Beets to Curly Top

J. M. FIFE[1]

Many studies have been made, in the past, in an attempt to correlate some property or the presence of some substance in sugar beet plants with resistance to curly top. In these investigations, comparative studies were made on the composition and the physical properties of juice expressed from different tissues of healthy and diseased plants of both resistant and susceptible varieties. The results of these comparative studies with plants grown in the greenhouse in sand culture, in heavily fertilized potting soil and with field-collected samples, often showed a greater variation among different plants of the same variety than between plants of resistant and susceptible varieties. When a number of plants were represented in the comparative studies, the differences found were not significant and frequently reversed.

It is known that under severe conditions of the disease a clear exudate often flows from the phloem of diseased leaves to the surface of the midrib and petiole through the intercellular spaces (3)[2]. Bennett (1, 2) has shown that this exudate collected over the bundles of diseased roots contains a high concentration of virus. A large amount of evidence has been accumulated also which indicates that the virus is more or less confined to the phloem and that multiplication may take place largely or only in the phloem. These findings have led to the conclusion that further studies should involve investigations of the chemistry of the phloem content. It is in this medium that one might expect to find the highest concentration of factors responsible for resistance.

It is known also that sugar beet roots will, under certain conditions which are not well understood, exude small amounts of liquid from the phloem tissue. Extensive tests of many collections made by the author (4) show this exudate to be strikingly different in composition and in physical properties from the expressed juice of the same roots and xylem exudate from similar roots. In view of the evidence that this exudate appears to be the phloem content in a relatively pure form, it should be of value for studies on the nature of resistance of sugar beets to curly top.

With the rapid advances made in the field of chromatography and by use of the newer ion exchange resins for the purpose of concentrating the samples, where necessary, the small volumes of phloem exudate which can be obtained from healthy and diseased sugar beet roots may be sufficient to find significant differences in the composition of phloem exudate from resistant and susceptible sugar beet plants. In view of such a promising method of attack on the problem, intensive studies have been undertaken using paper chromatography, to identify and to determine the relative

[1] Chemist, Sugar Plant Investigations, Field Crops Research Branch, ARS, U. S. Dept. of Agriculture, Riverside, California.

[2] Numbers in parentheses refer to literature cited.

amounts of amino acids, organic acids and other compounds in the expressed juice and in the phloem exudate from diseased and healthy sugar beet plants of resistant and susceptible varieties. The present paper is a report on the investigations made thus far.

## Methods and Results

Young beet plants of a variety susceptible to curly top were inoculated with a strain of virus which produced severe symptoms of the disease. After 21-28 days of growth in the greenhouse following inoculation, the leaves showing severe symptoms were collected and the petioles removed. Leaves of the same age were removed at the same time from healthy control plants. The juice was expressed from the frozen leaf samples and passed through a mat of celite which removed the chlorophyll. Thymol was added as a preservative and the juice stored at —10° F.

Four to 6 microliters of the undiluted juice were found to give the best unidirectional papergrams. These volumes of juice from healthy and diseased leaves were spotted on papers along with amino acid standards. One series of papers was developed in a phenol-water mixture while similar papers were developed in a butanol-acetic acid-water system by the ascending method. The temperature of the room was maintained at 23° C. with a relative humidity of 33 percent. The maximum variation in the room temperature was plus or minus one degree while the solvent and the air inside the jars was found to vary not more than 0.2° C.

When the solvent front reached approximately 25 cm. the papers were removed and dried, generally overnight, followed by two hours drying at 40° C. with air circulation. The papers were then sprayed with 0.5 percent ninhydrin in alcohol. Unidirectional papergrams, developed in phenol and a butanol-acetic acid-water system, using healthy and diseased juice of beet leaves and phloem exudate from diseased and healthy beet plants of resistant and susceptible varieties, are shown in Figure 1. Papergram A shows some of the striking differences found in the relative density of corresponding spots from healthy and diseased leaf juice.

It was found necessary to reduce the volume of juice from diseased leaves to one-tenth that of the healthy juice (the control) in order to make the density of the spots at Rf .50 approximately the same. Two directional papergrams revealed that the intensity of this spot in the diseased juice is due almost entirely to one amino acid. The amino acid has been tentatively identified as argenine. Aspartic acid, which is barely visible appeared to be present in both the healthy and diseased juice in approximately the same concentration while glutamic acid in all tests appeared to be considerably more concentrated in the healthy juice.

Papergram B (developed in butanol) shows three pairs of healthy and diseased juice. This papergram confirms the observations made from papergram A. With this solvent, as many as 10 distinct spots have been located on papergrams spotted with healthy and diseased juice. However, comparative spots were not found in all cases, indicating that certain amino acids may not be present in the juice of both healthy and diseased beet leaves.

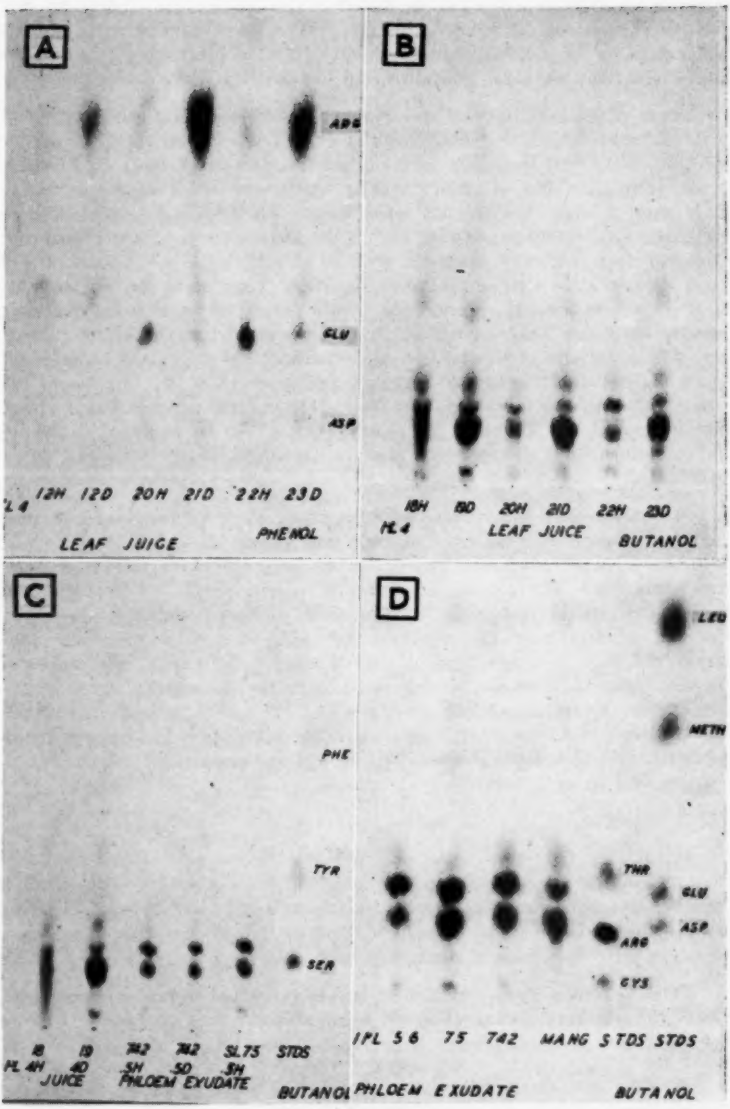


**Figure 1. Papergrams showing the amino acids in juice from healthy and diseased beet leaves and phloem exudate from healthy and diseased roots of resistant and susceptible varieties.**

The large extremely dense spot at Rf .12 in the diseased juice contains what has been tentatively identified as argenine. The papergram patterns and the differences in the relative density of corresponding spots were found to be uniform for the six pairs of healthy and diseased leaf juice studied.

The juice from healthy and diseased beet leaves was compared with phloem exudate collected from healthy and diseased roots of a susceptible variety (S. L. 742) and also with phloem exudate from roots of a variety resistant to curly top (U. S. 75). The results are shown in papergram C. In view of the fact that only 0.5 microliters of phloem exudate was sufficient to give a satisfactory papergram and at the same time produce comparative spots of approximately the same relative density as 4 microliters of leaf juice, it is evident that certain amino acids are present in the phloem exudate in concentrations several fold greater than in juice from expressed leaves. An amino acid, having an Rf value near that of the cysteine standard .08, is present in the healthy and diseased leaf juice and considerably more is present in the healthy phloem exudate of U. S. 75. A trace of this amino acid appears in the healthy susceptible phloem exudate but is apparently removed as a result of the disease. At Rf .10 an amino acid appears in the healthy and diseased leaf juice but is absent in the phloem exudate samples.

Unidirectional papergrams were prepared using phloem exudate from roots of two varieties resistant to curly top (U. S. 56 and U. S. 75), with exudate from a susceptible variety (S. L. 742) and with phloem exudate from mangels. The results are shown in papergram D. This papergram reveals differences mainly in concentration between amino acids in the phloem exudate from the resistant and susceptible roots. Distinct spots, at an Rf slightly below that of the standard cystein (Rf .07), appeared in the phloem exudate of the resistant varieties, whereas it is barely detectable in the susceptible variety S. L. 742 and is absent in mangels. At Rf .33, which is near the standard of tyrosine, spots are present in the resistant varieties but are absent in the phloem exudate of the susceptible variety and mangel.

## Summary

By the use of paper chromatography, striking differences were found in the relative concentration of certain amino acids in the juice expressed from healthy and diseased beet leaves and in the phloem exudate collected from healthy and diseased sugar beet roots.

Distinct differences were found between the papergram patterns made from the phloem exudate collected from resistant and susceptible varieties of sugar beet roots and from mangels.

## Literature Cited

(1) BENNETT, C. W.
1935. Studies on the properties of the curly top virus. Jour. Agri. Res. 50:211-141.

(2) BENNETT, C. W.
1937. Correlation between movement of the curly top virus and translocation of food in tobacco and sugar beet. Jour. Agri. Res. 54:479-502.

(3) ESAU, K.
1933. Pathologic changes in the anatomy of leaves of the sugar beet, *Beta vulgaris* L., affected by curly top. Phytopath. 23:343-424.

(4) FIFE, J. M.
Unpublished data.

# Sugar Beet Virus Yellows Influences Subsequent Curly Top Infection

N. J. GIDDINGS[1]

There are many areas in the western United States where both virus yellows and curly top occur in sugar beet-growing areas. This fact led the author to investigate the possible effects of virus yellows infection upon subsequent exposure of such plants to curly top infection.

Thirteen separate experiments have been conducted during 1952 and 1953. All yellows-infected plants were inoculated and checked by Dr. C. W. Bennett of the Riverside Field Station of the Division of Sugar Plant Investigations. The infected plants were allowed to develop until there was evidence of partial recovery from virus yellows before they were inocullated with curly top virus. Plants used as checks were of the same variety and age as those infected with yellows and were held under the same environmental conditions.

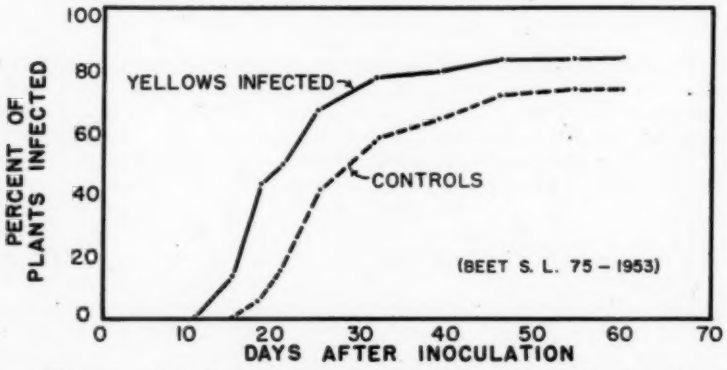


**Figure 1. Rate of curly top symptom development and final percent of curly top infection among sugar beet plants of the variety S. L. 75. Solid line indicates yellows-infected plants and broken line controls.**

The tests have included beet varieties S. L. 842, S. L. 75 and U. S. 22/3. Curly top inoculations were made with virus strains 1, 2, 3, 11 and 12 but strains 2, 3, and 12 gave low amounts of infection among plants of the curly top-resistant varieties and practically all inoculations were made with strains 1 and 11 after the first two experiments. The first "pilot" test included only ten check plants and 22 which were yellows-infected. The other 12 experiments included 1,133 plants, of which 511 were checks not infected with yellows and 622 were yellows-infected. Figure 1 gives a typical example

---

[1] Collaborator (formerly Senior Pathologist), Field Crops Research Branch, ARS, U. S. Department of Agriculture, Riverside, California.

[2] Numbers in parentheses refer to literature cited.

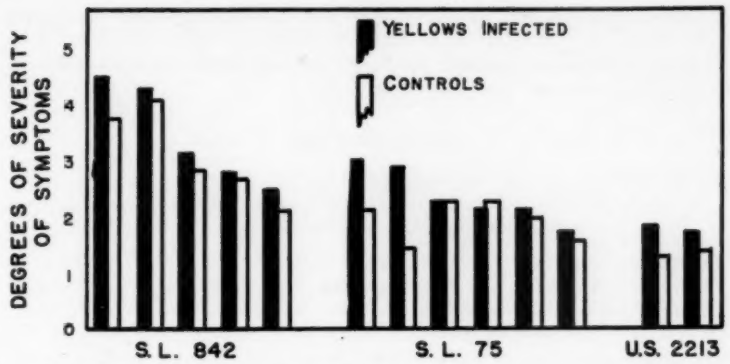


**Figure 2. Average severity of curly top symptoms shown by infected sugar beets approximately 6 weeks after inoculation. Solid black bar indicates yellows infected plants and adjacent outline indicates controls.**

of the rate of curly top symptom development and the final percent infection among yellows-infected plants and among control plants of the beet variety S. L. 75.

In each of the 13 experiments the appearance of curly top symptoms was distinctly more rapid in the plants which were diseased with virus yellows. In the first experiment, and in one other in which the susceptible beet variety S. L. 842 was used, the final amount of infection was 100 percent, but the controls were several days later than the yellows-infected plants in showing 100 percent curly top. In the other experiments the yellows-infected plants showed a final infection score which was from 3 percent to 23 percent higher than the controls and a general average that was well above 10 percent.

Evidence from the first few experiments indicated that the injury from curly top infection was more severe in plants which were previously infected by virus yellows than in comparable control plants. The data from all 13 experiments are given in Figure 2.

There are 11 tests in which the yellows-diseased plants show greater curly top injury than the controls. Based on a severity grade scale of 1 to 5, the greater amount of injury varied from 0.1 to 1.0 degrees of severity. In one experiment with beet S. L. 75 there was no difference and in another there was a reversal of 0.1. The results as a whole are statistically significant but are not so striking as those dealing with susceptibility to curly top infection and time required for curly top symptoms to appear.

Curly top virus is an obligate parasite. It will infect and develop in only a few specialized living tissues (1, 2). Other factors being equal the curly top virus normally appears to infect more readily and to develop more rapidly in plants which are growing vigorously. Virus yellows certainly interferes with the normal growth of sugar beet plants infected by it, yet it seems to induce some physiological disturbance in the beet which is favorable for curly top virus.

The important fact proved by this work is that sugar beet plants infected by virus yellows are more likely to become infected and injured by curly top. Control measures against virus yellows will help to some extent in keeping down the losses due to curly top.

## Literature Cited

(1) BENNETT, C. W. and ESAU, KATHERINE
1936. Further studies on the relations of the curly top virus to plant tissues. Jour. Agr. Res. 53:505-620.

(2) LACKEY, C. F.
1946. Occurrence of curly top virus in meristematic tissue. Phytopathology 36:426-468.

# Effect of Virus Yellows on the Yield and Sucrose Percentage of the Sugar Beet at Salinas, California, in 1952

J. S. McFarlane, C. W. Bennett and A. S. Costa[1]

A problem of severe yellowing of sugar beets during the late spring and summer months has been under study in the Salinas Valley of California for several years. In September, 1951, Dr. Raymond Hull, a specialist on virus yellows from the Rothamsted Experiment Station in England inspected beet fields around Salinas and stated that the symptoms of many of the yellowed plants were comparable to those of European plants known to be affected with virus yellows. Coons (1)[2] reported the results of transmission and serological tests which definitely established that the yellows virus was one cause of yellowing of sugar beets in the Salinas Valley. This paper reports the results of two experiments conducted at Salinas in 1952 to measure the damage to sugar beets from virus yellows resulting from natural infection.

## Experiment 1

One-half acre of the U. S. 56/2 variety was planted February 26, 1952, adjacent to an overwintered planting of miscellaneous sugar beet varieties. The beets were planted on beds 28 inches apart and were thinned to nine inches in the row. The planting was divided into six replications and each replication into two plots. Strips of barley approximately five feet in width were planted along the sides of the planting, between the replications and between the plots in such a manner that each of the plots was surrounded by a barley barrier. The purpose of the barrier was to reduce the migration of the aphid vector from one plot to another.

One plot in each replication was sprayed with demeton (systox) to control aphids, and the second plot was left unsprayed. The first application was made April 5 at the rate of 140 cc. demeton (32 percent) per acre. Four applications were made at the 140-cc. rate. Beginning June 13, the rate was increased to 168 cc. of demeton per acre in order to compensate for the larger size of the plants. Four applications were made at the 168-cc. rate, the last application being made July 28. The first application was made with a power sprayer and the remainder with a knapsack sprayer.

Counts of plants showing virus yellows symptoms were made July 8, 1952, and the results are shown in Table 1. The percentage of plants with yellows symptoms varied greatly among replications and also among plots. In replications 1, 3, and 5, the unsprayed plots were separated from the overwintered beet planting by only the five-foot barley barrier whereas in replications 2, 4, and 6, the reverse situation existed and the sprayed plots were closest to the overwintered planting. These results show that infective aphids moved into the plots from the overwintered beets and that the in-

[1] Geneticist and Principal Pathologist, Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture, and Pathologist, Instituto Agronomico, Campinas, Brazil, respectively.

[2] Numbers in parentheses refer to literature cited.

fection was greatest in those beets closest to the source of infection. Infection was about three times greater in the unsprayed plots than in the sprayed plots when they occurred adjacent to the source of infection. When the sprayed plots occurred closest to the source of infection, there was slightly more infection in the sprayed than in the unsprayed plots.

**Table 1.—A Comparison of the Percentage of Plants with Virus Yellows in Demeton-Sprayed vs. Unsprayed Plots of Sugar Beets Planted February 26 and Counted July 8, 1952.**

| Replication No. | Percent of Yellowed Plants | |
|---|---|---|
| | Sprayed | Unsprayed |
| 1 | 5 | 24 |
| 2 | 12 | 10 |
| 3 | 7 | 16 |
| 4 | 16 | 14 |
| 5 | 13 | 33 |
| 6 | 15 | 11 |
| Average | 11 | 18 |

Variability in the amount of yellows infection and in the degree of control made it inadvisable to harvest the experiment on a complete plot basis. July 8, 100 beets in each replication with typical virus yellows symptoms were staked and on August 6, 100 healthy beets were staked in each replication. No healthy plants were staked which occurred next to diseased plants. The staked beets were harvested October 7 and the results are shown in Table 2. No difference was found in the yield of healthy as compared with yellowed beets but the sucrose percentage was one percent lower for the yellowed beets.

**Table 2.—A Comparison of the Yield, Sucrose Percentage, and Other Qualities of Healthy vs. Virus Yellows-Infected Sugar Beets Planted at Salinas, California, February 26 and Harvested October 7, 1952.**

| Treatment | Wt. of 100 Beets | Sucrose | Purity | Na | Amino N |
|---|---|---|---|---|---|
| | Lbs. | % | % | PPM | % |
| Healthy | 208 | 17.64 | 92.6 | 242 | .25 |
| Yellows-infected | 204 | 16.57 | 91.5 | 324 | .27 |
| | NS | HS | NS | S | NS |

NS—Not significant
S—Significant (odds 19:1)
HS—Highly significant (odds 99:1)

## Experiment 2

A four-acre block within a commercial field of sugar beets near Salinas, California, was selected for experimentation with virus yellows control. The field was planted with the U. S. 15 variety April 4, following standard cultural practices for the area. The four-acre block was divided into five replications measuring 130 feet by 270 feet. Each replication was divided into two plots, one of which was dusted with five percent malathion dust at the rate of approximately 45 pounds per acre, and the second left undusted. A total of six applications was made with a tractor-mounted duster beginning April 17 and ending July 1.

Four hundred plants in each plot were counted and observed for virus yellows symptoms August 7. The results of these counts are shown in Table 3. The percentage of plants showing virus yellows symptoms averaged about 3 percent in the dusted plots as compared with about 20 percent in the non-dusted plots. These results show that naturally occurring virus yellows infection can be significantly reduced by controlling the aphid vector with frequent applications of malathion dust.

**Table 3.—A Comparison of the Percentage of Plants Showing Virus Yellows Symptoms in Malathion-Dusted vs. Non-Dusted Plots of Sugar Beets Planted April 4 and Counted August 7, 1952.**

| Replication No. | Percent of Yellowed Plants | |
|---|---|---|
| | Dusted | Non-Dusted |
| 1 | 6.0 | 29.0 |
| 2 | 2.3 | 17.8 |
| 3 | 2.0 | 14.3 |
| 4 | 4.3 | 22.5 |
| 5 | 2.3 | 14.0 |
| Average | 3.4 | 19.5 |

The relatively low percentage of infection in the experimental area and lack of complete control in the dusted plots made it inadvisable to harvest the experiment as complete plots. One hundred yellowed plants and 100 healthy plants were staked in each of the five non-dusted plots August 7. In order to reduce bias, healthy plants were staked by selecting every third, fourth, fifth, or sixth healthy plant in any particular row. No healthy plants adjacent to diseased plants were staked. In cases where the count fell on a mildewed or yellows plant, the next competitive plant in the row, not adjacent to a diseased plant, was staked.

The staked plants were harvested October 10 and the results are shown in Table 4. Both the yield and sucrose percentages of the yellowed beets were lower than those of the healthy bets. The yield was reduced by one-third and the sucrose percentage was a full percent lower.

**Table 4.—A Comparison of the Yield, Sucrose Percentage, and Other Qualities of Healthy vs. Virus Yellows-Infected Sugar Beets Planted at Salinas, California, April 4 and Harvested October 10, 1952.**

| Treatment | Wt. of 100 Beets | Sucrose | Purity | Na | Amino N |
|---|---|---|---|---|---|
| | Lbs. | % | % | PPM | % |
| Healthy | 255 | 16.44 | 83.3 | 584 | .47 |
| Yellows-infected | 165 | 15.33 | 87.7 | 748 | .43 |
| | HS | HS | NS | NS | NS |

NS—Not significant
HS—Highly significant (odds 99:1)

## Conclusions and Summary

These two experiments demonstrated that the yellows virus is an important cause of yellowing of sugar beets in the Salinas Valley of California.

Through the use of demeton spray and malathion dust the aphid vector of the virus was partially controlled and the amount of infection was reduced but not prevented.

In both experiments the sucrose percentage of virus-yellows-infected beets was one percent lower than that of healthy beets, but the results with yields were inconsistent. In experiment 2, the yield of the yellowed beets was one-third less than that of the healthy beets whereas in experiment 1, there was no significant difference in the yield of yellowed and healthy beets.

These results indicate that a reduction in the yield of gross sugar occurs in the Salinas Valley from virus yellows infection but additional tests are required before accurate estimates of the loss can be made.

ACKNOWLEDGMENT

We wish to express our appreciation to Dr. G. H. Coons and Dr. Floyd F. Smith of the Agricultural Research Service, United States Department of Agriculture, for valuable aid in planning the experiments. Myron Stout, C. H. Smith, and G. K. Ryser of the Agricultural Research Service, Salt Lake City, Utah, rendered valuable assistance in making the chemical determinations and in analyzing the data. We also thank the American Cyanamid Company for supplying the malathion dust.

## Literature Cited

(1) COONS, G. H.
1952. Virus yellows of the sugar beet in the United States. Plant Disease Reporter 36: 356-363.

# Results of an Experiment in Colorado to Appraise Effects of Virus Yellows in Sugar Beet[1]

G H. Coons, John O. Gaskill and Leslie B. Daniels[2]

Virus yellows may affect all or nearly all plants in the field and may occur so generally in a district that no healthy fields or portions of fields are available to serve as measuring sticks of what the crop might be without virus yellows. The period of disease onset whether early or late is extremely important with respect to crop damage, early infections being far more serious than those occurring in late season. As a further complication, other conditions may bring about a yellowing of foliage which superficially resembles virus yellows. For these reasons the assessment of losses caused by the disease presents some difficulties.

In Europe, a long period ensued after the first outbreaks of virus yellows were noted in sugar beets before the condition was recognized as an infectious plant disease. After that a considerable period elapsed before growers and processors became convinced that virus yellows may cause serious losses. Watson, Watson and Hull (5)[3] by a series of experiments begun in 1942 showed that plants which were infected in June or July lost half or more of their potential yield of sugar. The loss in sugar production varied directly with the length of infection period and amounted to 3 to 5 percent of the yield of healthy plants for each week of infection between the appearance of visible symptoms and harvest. Hull (3) states that numerous infection tests made in recent years have confirmed these findings. The experimental results were obtained from a series of replicated plots. The inoculation technique employed in the British experiments was to place five aphids (*Myzus persicae*) which had been fed on virus yellows plants upon each sugar beet plant to be infected. Plants not infested with aphids served as controls. After 24 hours the entire experimental area was fumigated with nicotine vapor.

On the basis of a number of experiments in the Netherlands, as reported by Hartsuijker (2), 100 percent virus yellows infection at the end of June or beginning of July was estimated as causing 25-30 percent loss in sugar production. Björling (1) in his experiments in Sweden showed 61 percent decrease in sugar yield for parcels infected 100 percent on June 30, in comparison with parcels not infected. The difference fell to 34 percent for total infection July 20 versus non-infected.

Schloesser (4) in a replicated test at Buir, Germany, compared yields from plots subject to natural infestation of *Myzus persicae* carrying both virus yellows and beet mosaic with those in which insect infestation was largely prevented by spraying with a systemic insecticide (E605). The

---

[1] Sugar beet investigations of the U. S. Department of Agriculture in Colorado are conducted in cooperation with the Colorado Agricultural Experiment Station. This article has been approved for publication by the Station Director as Scientific Series Article No. 442.

[2] Principal Pathologist, Field Crops Research Branch, Agricultural Research Service, U. S. Dept. of Agriculture, Beltsville, Md.; Pathologist, Field Crops Research Branch, Agricultural Research Service, U. S. Dept. of Agriculture, Fort Collins, Colo.; Chief Entomologist, Colorado Agricultural Experiment Station, Fort Collins, Colo., respectively.

[3] Numbers in parentheses refer to literature cited.

spraying was reported to have held infection to a minimum. The period of infestation of the plots by the aphids was prevailingly at the end of June and the beginning of July, a date considered moderately early in the Rhineland for virus yellows infection. Two varieties were included in the test. The unsprayed plots of Kleinwanzleben E had an average root yield 23 percent below the yield of the plots treated with the systemic insecticide, a polariscope reading reduced by 0.68, and a 26 percent drop in sugar production. The corresponding figures for Kleinwanzleben CR, the other variety, were 18 percent reduction in root yield, 0.67 less in polariscope reading and 21 percent reduction in sugar production attributable to the insect-borne diseases.

In his tests Schloesser found that virus yellows combined with mosaic affected all important attributes which are concerned with returns from the beet crop, especially those related to quality. The soluble ash content increased in roots from diseased plots over that from the roots of sprayed plots and harmful nitrogen similarly was increased. The drop in polarization was less than has been reported for other experiments from early and severe virus yellows infections.

The severe losses caused by European virus strains do not necessarily mean that the strains of yellows virus in the United States will cause similar losses. Dr. Hull, on the basis of his observations of field symptoms in Colorado, Utah, California and Michigan, considered our strains to be of mild type, an opinion borne out by limited tests which he and Schloesser have been able to carry on with diseased plants sent from the United States.

It is therefore important to determine under our conditions, and with the strain or strains of yellows virus which occur here, the effects of the disease upon the sugar beet crop. An experiment was planned in which healthy plants and those affected with virus yellows were to be compared for yield and quality. Three dates of inoculation, namely, early, medium, and late season, were to be employed to give differential lengths of disease involvement. The yellows virus was to be the strain, or strains, found in the vicinity of Fort Collins, Colorado.

Viruliferous aphids were to be placed on all the sugar beet plants in the two center rows of the 8× replicated plots at a given inoculation date, hence the onset of the disease would be at approximately the same time for these plots. For each inoculation date series, a similar number of adjacent plots not exposed to aphids was set up to serve as checks. The spread of aphids from the infested plots to the non-infested plots was to be prevented by frequent nicotine sulphate sprays which would also control, to some extent, aphids which might fly into the field from outside.

The design of the experiment called for the groups of plots for each of the three inoculation dates (early, medium, and late season) to occur at random in two blocks. Within the inoculation-date group of a block, the four infested and the four control plots were randomized. There were eight plots for each treatment at each inoculation date. Each plot consisted of four rows 25 feet long. The rows were 20 inches apart. The field chosen for the experiment had an excellent stand of the sugar beet variety GW 304.

On June 16 the first infestation with aphids was made. Only the two inner rows of the plot to be infested received the viruliferous aphids, about five to ten individuals, placed on each plant of these rows. The second inoculation with aphids as the vector of the virus was carried out July 16, following the same techniques; the late inoculation scheduled for August 10 was not carried out.

The colonies of *Myzus persicae* in this experiment were grown by the Entomology Section of the Colorado Agricultural Experiment Station. The aphids were hatched from eggs obtained from peach buds collected at Grand Junction, Colorado. Sugar beet roots known to be infected with virus yellows typical of that which occurred generally in the fields around Fort Collins were collected in October, 1952, from a field near Johnstown, Colorado, which was severely affected with virus yellows but apparently entirely free from beet mosaic. The roots were potted in early spring in the greenhouse and the new growth from each was tested by means of juice inoculations of healthy beet seedlings to make sure that beet mosaic was absent. No evidence of beet mosaic was found. They were put in cages and the virus-free *Myzus persicae* colonized on them.

By June 16 the leaves of the source plants for the yellows virus were heavily infested with aphids. The leaves were cut into small pieces with as little disturbance to the aphids as possible. The pieces were dropped into vials, each vial receiving not less than five aphids. Within a half hour, on the average, a crew of men in the field placed the small pieces of leaf and aphids on the young sugar beet plants, the contents of one vial being used for each plant. Conditions were excellent for aphid transfer at both infestation periods and the insects promptly moved to the young sugar beets.

Unfortunately, nicotine sulphate used as a spray to kill the aphids in the infested field after the June 16 inoculation was not entirely effective, so that viruliferous aphids moved into the control plots from the infested plots. These aphids plus any viruliferous aphids which may have come from adjacent fields led to a heavy incidence of virus yellows in the plots that should have been nearly yellows free. When it was found that the nicotine sulphate applications were not effective, a spray of tetraethyl pyrophosphate, TEPP, was substituted. TEPP gave a satisfactory kill.

The second inoculation date was July 16 and the same program for aphid transfer was followed. The spread of infectious insects from the inoculated plots to the checks was largely prevented by the TEPP spray, but because of the earlier movement of aphids from the infested plots occasioned by failure of nicotine sulphate to give an effective kill, together with movement of aphids from outside fields, the control plots in this series developed considerable virus yellows, the average for all control plots for this date of infestation being 32 percent. This high incidence, however, was in marked contrast to the control plots of the earlier infestation which showed, on the average, 64 percent virus yellows.

The results of the experiment, based on the entire plant population in the two inner rows of each plot, are summarized in Table 1.

**Table 1.—Acre Yields of Roots and Sugar and the Sucrose Percentages from non-inoculated Plots and from Plots Inoculated with Virus Yellows by Means of *Myzus persicae:* Two Dates of Inoculation. All Plants in 40 Feet of Row Per Plot Harvested. Bay Farm, Fort Collins, Colorado, 1953. Results Given as 8-Plot Averages.**

| Treatment | Acre-yield | | Sucrose | Plants per 100′ row | Incidence of virus yellows 9/29 |
|---|---|---|---|---|---|
| | Gross sugar | Roots | | | |
| | Pounds | Tons | Percent | Number | Percent |
| A. June 16 inoculation: | | | | | |
| Not inoculated | 5,350 | 16.43 | 16.27 | 105 | 64 |
| Inoculated | 5,248 | 16.14 | 16.28 | 106 | 93 |
| Difference | 102 | 0.29 | 0.01 | | |
| B. July 16 inoculation: | | | | | |
| Not inoculated | 5,752 | 17.53 | 16.41 | 98 | 32 |
| Inoculated | 5,372 | 16.34 | 16.44 | 102 | 92 |
| Difference | 380[1] | 1.19[1] | 0.03 | | |

[1] Differences marked are significant at 5 percent point.

No significant differences in acre yields of roots or sugar or in sucrose percentage were found between the early-inoculated plots and the non-inoculated plots set up as controls. In view of the high percentage of obvious virus yellows in the control plots, and since such readings may not fully reflect the incidence of the disease, little contrast between the inoculated plots and the control plots was to be expected. For the individual control plots, the readings of the number of plants obviously diseased with virus yellows up to September 29 were as follows: 76, 79, 64; 27, 73, 49, 59, and 84 percent; whereas, the inoculated plants gave readings of 98, 88, 93, 97, 91, 95, 84, and 95 percent virus yellows. Obviously there were not enough plants free from virus yellows in the control plots to bring about substantial yield differences.

The results from the series of plots inoculated with virus yellows July 16 show some significant differences. As shown in the table, the inoculated plots which averaged 92 percent virus yellows yielded significantly less than the control plots in spite of the fact that these averaged 32 percent virus yellows. The difference in root yield was 6.8 percent and the difference in sugar yield was 6.6 percent in favor of the controls. No appreciable difference in sucrose percentage between the inoculated plots and the controls was found. Clearly, virus yellows infection had a depressing effect on root growth.

In the July 16 series, as an average, 32 percent of the plants of the control plots had been staked by September 29 as showing virus yellows. This average, however, is misleading since the readings of virus yellows plants in the individual control plots ran 71, 27, 49, 56, 14, 3, 20, and 18 percent. The plots infested with viruliferous aphids read 93, 83, 93, 93, 88, 92, 95, and 95 percent virus yellows. Considering only the 5 control plots showing the least virus yellows and the 5 comparable infested plots, the latter averaged 11.4 percent less than the controls in yield of roots and 10.6 percent less in yield of gross sugar. The difference in sucrose percentage was negligible.

In considering the results from this test, it may be assumed that whatever natural virus yellows infection may have occurred before the inocula-

tions were made July 16 was balanced over the plots, that the virus yellows counts are low rather than high since only obviously diseased plants were noted, and that the high percentage of virus yellows in the control plots obscured to a very marked degree the contrasts between the inoculated and non-inoculated plots.

If the heavily infected plots when contrasted with those presumably only one-third infected show 6.8 percent reduction in weight of roots it is reasonable to assume that if the comparison could have been made between plots 100 percent diseased and 100 percent healthy then the difference would be more nearly on the order of 10 to 15 percent. The results obtained by selecting five of the least infected control plots for comparison with their neighboring infected plots support this assumption.

In Europe, as we have seen, differences in readings of sucrose percentage of 1 to 2 numerical percents may occur between early-infected and non-infected plants, although there is considerable variation with respect to this attribute. The data from this test do not show that virus yellows affected sucrose percentage.

This experiment represents the first attempt to appraise virus yellows effects in Colorado by means of controlled inoculations. Results over several years are needed. The techniques for infesting the plots with aphids, and for obtaining a complete kill to prevent the spread of viruliferous aphids to the control plots, have been explored. From the results, it is clear that infection from outside the experimental area also needs to be prevented. An experiment of this sort must be replicated many times to avoid bias which might come from soil heterogeneity and the entire area must be sampled. The sprayer as it is used for insect control must traverse the entire area to avoid differences in degree of soil compaction and of mechanical injury to the foliage; the insecticide used must not be such that its residues interfere with subsequent inoculations of plots in a late series by means of aphids. Next year's work should be done with greater effectiveness and some additional factors will be introduced to throw more light on the virus yellows problem.

## Summary

Effects of virus yellows on sugar beet yield and quality were studied in a replicated test at Fort Collins, Colorado, in 1953 with the virus strain or strains prevalent there. Inoculations were made with viruliferous aphids.

Plots inoculated July 16 developed 92 percent obvious infection by September 29; the control plots did not remain free from virus yellows, but showed an average of 32 percent. The average root yield of the artifiicially infected plots was 6.8 percent less than that of the controls, a significant difference. Effect on sucrose percentage was negligible.

It is estimated that if the comparison could have been based on 100 percent diseased versus 100 percent healthy plants, virus yellows would have shown a repression of root growth of between 10 and 15 percent.

## Literature Cited

(1) BJORLING, K.
1949. Virusgulsot hos betor. Sjukdombild och inverkan pa den Svenska Sockerbetsskorden. Socker. 5:119-140.

(2) HARTSUIJKER, K.
1952. De Vergelingsziekte der Bieten, I. Med. Inst. Rationele Suikerproductie. 21:17-275.

(3) HULL, R.
1953. Assessments of losses in sugar beet due to virus yellows in Great Britain, 1947-52. Plant Pathology. 2 (2) :39-43.

(4) SCHLOESSER, L. A.
1951. Infektionszeitpunkt und Ertragsminderung bei gelbsuchtinfizierten Beta-Ruben. Nachrichtenblatt des deutschen Pflanzenschutzdienstes. 3 (5) :2 pp.

(5) WATSON, MARION A., WATSON, D. J., and HULL, R.
1946. Factors affecting the loss of yield of sugar beet caused by beet yellows virus. I. Rate and date of infection; date of sowing and harvesting. Journ. Agr. Sci. 36 (6) :151-166.

# Histological Changes Produced by Virus Yellows In Sugar Beet Leaves

C. F. LACKEY[1]

Greenhouse investigations, as well as extensive field observations of virus yellows in California, have been carried on by C. W. Bennett and A. S. Costa. They determined some of the common symptoms found in the field and a great variety of symptoms in the greenhouse. Histological studies of virus yellows were prompted by the unusual variety of symptoms appearing on infected beets in the greenhouse.

Information on tissues injured is an aid in identifying viruses.

## Materials and Methods

The infected leaves for study of general yellowing in the field were obtained from a sugar beet field near Riverside, California. The greenhouse material was furnished by C. W. Bennett and A. S. Costa from sugar beets inoculated by aphids.

The fixed and sectioned material was stained with dilute hematoxylin, counterstained with safranin and sometimes in addition stained with light green in clove oil.

Fresh material was hand-sectioned in the usual way between pieces of corn pith and examined under the microscope.

## Studies on Material from the Field

The most common field symptom of virus yellows is a general yellowing of older leaves. Veins are sometimes green at first, but eventually become entirely yellow. In addition these leaves become thickened and brittle with surfaces uneven, especially on the underside. Figure 1A shows a healthy leaf section and Figure 1B a yellowed section. Transverse sections of healthy, mature leaves show relatively even flat surfaces on both sides of the leaves. In the palisade area, the cells are long and loosely packed with rather large intercellular spaces as shown in Figure 1A. Similar sections of yellows-infected leaves show greater thickness with uneven, undulate surfaces. More striking effects are small, short, closely packed cells practically devoid of intercellular spaces. This condition prevails to some degree throughout the entire leaf. There was no sign of necrosis or degeneration visible in these yellows-infected leaves.

## Studies of Symptoms of Material from the Greenhouse

Sugar beets inoculated with virus yellows in the greenhouse have shown a variety of symptoms, some of which are not common in field plants.

The following symptoms occur in the greenhouse: vein clearing, pinpoint cleared spots, and pimples with cleared spots which sometimes have necrotic areas in the center of some of the spots. Sometimes there is a form of etching on the upper side of veins which causes the veins to appear brown-

[1] Plant Pathologist, Field Crops Research Branch, Agricultural Research Service, U. S. Dept. of Agriculture, Riverside, California.

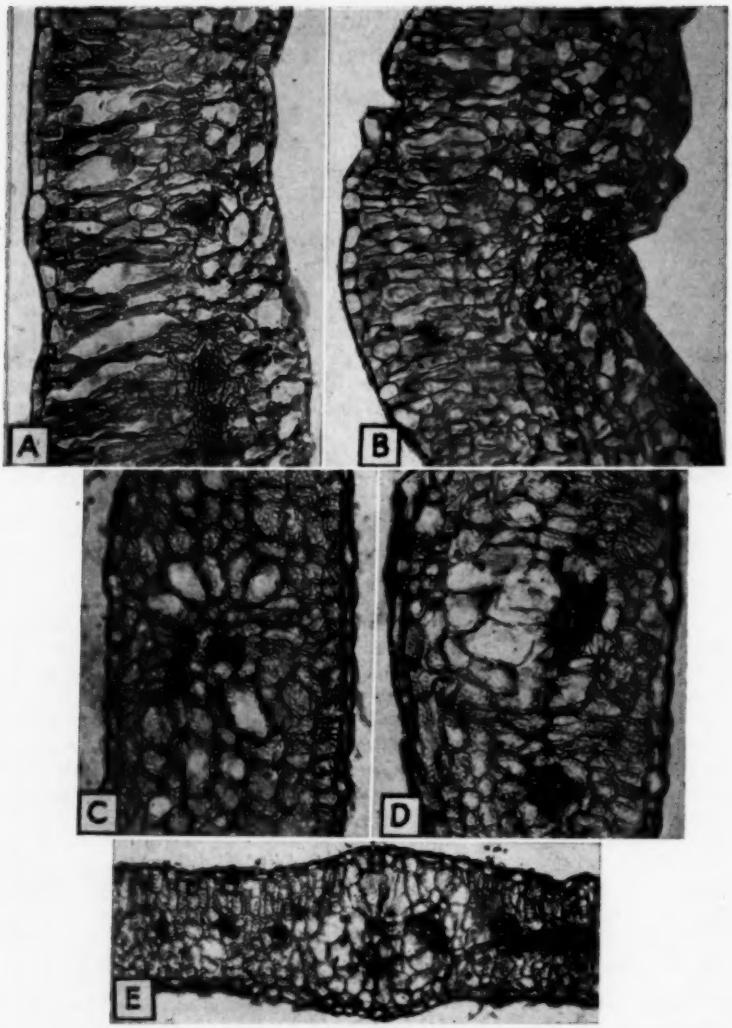


**Figure 1.—Virus yellows symptoms in leaves of beets from field and greenhouse. A. Cross section of healthy leaf from field. B. Cross section of diseased leaf from field showing uneven surfaces, thickened condition and small closely packed cells devoid of intercellular spaces in palisade area. C. Cross section through small cleared vein showing necrosis in vein and enlarged cells almost devoid of chlorophyll. D. Pimple, showing greatly enlarged cells on lower side of necrotic vein. E. Pimple protruding on both surfaces of a beet leaf.**

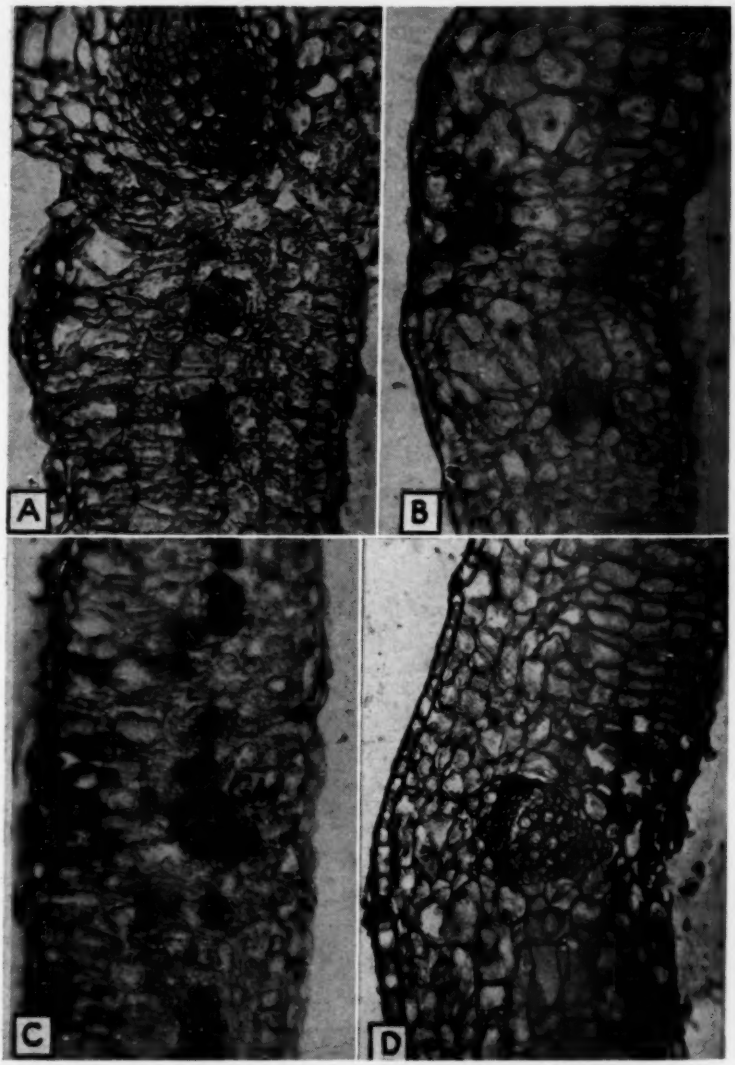


**Figure 2.—Symptoms of virus yellows in sugar beet leaves. A. Necrosis of cells in large vein and beneath epidermis. B. Necrosis in large pimple involving parenchyma cells beneath epidermis. C. Necrotic spots in epidermis, and large cell inclusions of granular material (GM). D. Internal symptoms of "etch" showing necrotic cells following vein with necrosis in phloem in the side opposite necrotic parenchyma cells.**

ish. There are also completely necrotic spots of various sizes in older leaves and irregular chlorotic spots known as flecking. The latter is a common symptom found in the greenhouse. Freehand sections of fresh leaves with vein clearing showed cells around the small veinlets to be considerably enlarged and almost devoid of chloroplasts. The chloroplasts present were not only fewer in number but smaller than in the tissues further away from the veins. In larger clear veins most of the cells of the lower protruding part of the veins had relatively few chloroplasts and little chlorophyll. Stained sections of fixed material showed necrosis in the bundles of the small cleared veins. In addition, the enlarged cells surrounding these were nearly devoid of chlorophyll, as shown in Figure 1C.

Pin point clear spots and pimples may result from inoculation of plants under greenhouse conditions. Pimples are produced, usually on the underside of the leaf (Figure 1D), but some appear on both sides, as in Figure 1E. The pimples and cleared spots are associated with necrotic veinlets, and the hypertrophied parenchyma cells may be on one or both sides of the veinlet, thus producing pimples on one or both leaf surfaces.

Flecking seems to be due to destruction of chlorophyll in groups of parenchyma cells near a necrotic vein. This phenomenon is somewhat similar to "pinpoint" cleared dots, but without the excessive hypertrophy of parenchyma cells.

There are also necrotic lesions producing more conspicuous symptoms consisting of much larger necrotic areas on the leaf surface. These resemble the larger local leisons of some of the rubbed on inoculations of other kinds of virus diseases.

As seen in Figures 2A and 2B, there is necrosis in veins, phloem of large veins, and in parenchyma cells beneath the epidermis. In some cases this necrotic condition also affects the epidermis, as shown in Figure 2C. There was also a great increase in the number of large cell inclusions. These appeared to be composed of granular material (GM).

An unusual symptom designated as "dark etch" is characterized by dark brown lines over the veins on the upper surface of the older leaves. This is caused by necrosis of the epidermis and 2 or 3 layers of cells beneath. In some cases only the epidermis and a single layer of cells are involved, thus leaving 2 to 4 layers of unaffected cells between the necrotic area and the vascular bundle. The vascular bundle may show necrosis in the phloem of veins which show this etching effect, as illustrated in Figure 2D.

## Summary and Conclusions

Virus yellows produces yellow, thickened and brittle leaves under field conditions. The greater thickness and increased brittleness of leaves appears to result from production of increased numbers of parenchyma cells which are so closely compacted that little intercellular space remains. No necrosis was observed in vascular bundles of leaves of field plants.

On greenhouse plants the disease produces pimples, vein clearing, etch, irregular chloretic and necrotic spots, yellow splotches, and some yellowing

of entire leaves. Vein clearing and pimples result from hypertrophy of cells immediately adjacent to veins. Since these hypertrophied cells contain little chlorophyll they produce translucent spots or lines and sometimes bulging of overlying tissue. Usually, at least a few necrotic cells were present in the phloem. Etching of the veins is caused by death of a certain number of superficial cells along the veins. Chlorotic or necrotic flecks of spots result usually from injury to epidermal and adjacent parenchyma cells in localized areas. Degree of injury determines the character of the spot. Spots superficially similar to flecks may be caused by groups of closely placed pimples. No cytological explanation of production of yellow spots and leaf yellowing, other than fading of chloroplasts in affected cells, was obtained.

# Observation and Studies of Virus Yellows of Sugar Beet in California

C. W. Bennett and A. S. Costa[1]

Virus yellows has been known for many years as a disease of sugar beet in Europe but it was not until 1951 that it was reported by Coons and Kotila (3)[2] to be present in the United States. In 1952 Coons (1) reported that the disease was present in all of the major sugar beet-producing states of the country.

Surveys in 1952 and again in 1953 indicate that virus yellows occurred in all of the areas in central California where sugar beets were grown, and the disease was found also near Oxnard and Riverside in the southern part of the state. It has not been found in the Imperial Valley or in the Hemet Valley where beets are grown as a seed crop.

In the Imperial Valley beets are planted in the fall and harvested the following spring. There is a period, roughly from July to September, during which few plants are available to serve as potential sources of infection for the fall planting. It is possible that even if the virus were introduced it would not persist through the summer in quantity sufficient to cause widespread infection in the commercial crop under present conditions of sugar beet culture employed in this area.

In the Hemet Valley the seed crop of beets is planted mainly in August and harvested the following June to July. But in this area many escaped beets grow throughout the year in waste places and often growth from stubble of the seed fields lives through the summer and could serve as a source of infection for the succeeding crop if the virus were present. In fact, many of the escaped and stubble plants are infected with beet mosaic and serve as sources for extensive mosaic spread to the fall plantings. The fact that virus yellows has not been found in this area probably indicates that it has not yet been introduced there.

## Host Range and Symptoms

All varieties of sugar beet, table beet, and fodder beet which have been tested are susceptible to virus yellows. The disease occurs also on spinach and certain weed plants. In the Salinas Valley *Chenopodium album* (lambsquarters) in fields of sugar beet and spinach, has been found with a high percentage of the plants showing virus yellows. Occasionally, also, infected plants of *Chenopodium murale* (sowbane or nettleleaf goosefoot) occur in badly diseased beet fields.

Studies of the host range of the yellows virus under greenhouse conditions have indicated that the range of susceptible species is rather wide. All of the species of the genus *Beta* tested have shown signs of disease and some

---

[1] Principal Pathologist, Field Crops Research Branch, ARS, U. S. Dept. of Agriculture, Riverside, Calif., and Pathologist, Instituto Agronomico, Campinas, Brazil respectively.

[2] Numbers in parentheses refer to literature cited.

of them, notably *Beta macrocarpa,* appear to be even more susceptible to injury than sugar beet. The following plant species of the indicated families have been found susceptible to virus yellows under greenhouse conditions:

### AMARANTHACEAE

*Amaranthus albus*
*Amaranthus graecizans* tumbleweed
*Amaranthus palmeri*
*Amaranthus retroflexus* pigweed
*Celosia argentea* coxcomb
*Celosia* sp.
*Gomphrena globosa* globe amaranth

### AIZOACEAE

*Tetragonia expansa* New Zealand spinach

### CARYOPHYLLACEAE

*Stellaria media* chickweed

### CHENOPODIACEAE

*Atriplex bracteosa*
*Atriplex canescens* shad-scale
*Atriplex elegans*
*Atriplex elegans* var. *fasciculata*
*Atriplex expansa* fogweed
*Atriplex patula* var. *hastata* fat-hen
*Atriplex hortensis*
*Atriplex rosea* red-scale
*Atriplex semibaccata* Aust. saltbush
*Beta lomatagona*
*Beta macrocarpa*
*Beta maritima*
*Beta patellaris*
*Beta patula*
*Beta procumbens*
*Beta trigyna*
*Beta vulgaris* beet
*Chenopodium album* lambsquarters
*Chenopodium amaranticolor*
*Chenopodium murale* sowbane
*Chenopodium leptophyllum*
*Chenopodium urbicum*
*Chenopodium watsonii*
*Cycloloma atriplicifolium*
*Monolepis nuttalliana*
*Salsola kali* Russian thistle
*Spinacia oleracea* spinach
*Suaeda fruticosa* alkali blite

### PLANTAGINACEAE

*Plantago erecta*

### SOLANACEAE

*Nicotiana clevelandii*

Symptoms of virus yellows usually begin to appear in early May in fields of beets which are planted in December, January or February. First evidence of disease is usually a yellowing of older leaves in splotches, sectors or at the leaf tip. Yellowing may proceed on affected plants until all of the older leaves yellow, and become leathery and brittle. Lower leaves die prematurely. Usually, young leaves are normal and remain green until they approach maturity. However, at least one strain of yellows virus is known which is capable of producing distinct vein clearing in half-grown leaves under field conditions. This strain appears not to be widely distributed. Usually the plants recover from the yellowing to an appreciable degree by production of new leaves which show a lesser degree of yellowing. Fields that are very yellow in June may show much less evidence of the disease later in the season.

Symptoms of virus yellows differ appreciably in different species of plants under greenhouse conditions. On sugar beet they range from hardly perceptible yellowing on older leaves to severe yellowing and necrosis of older leaves and marked vein clearing of younger leaves. Plants of some species such as *Beta macrocarpa, Cycloloma atriplicifolium,* and *Stellaria media* (chickweed), *Atriplex semibaccata* (Australian saltbush), and *Bassia hyssopifolia,* show no evidence of the disease although they may carry high concentrations of yellows virus. *Salsola kali* (Russian thistle) is dwarfed but otherwise shows no evidence of the disease. Infected plants of *Chenopodium amaranticolor* are dwarfed and show a distinct type of mottle which continues to be produced on new leaves as long as the plants grow vigorously. All strains of the virus appear to affect this species with about equal intensity.

## Methods of Spread of Virus Yellows

**Tests for Seed Transmission.** Seeds of several varieties of diseased sugar beet plants were planted in the greenhouse and the seedlings were transferred to pots and watched for the appearance of symptoms of disease. None of more than 5,000 seedlings showed evidence of virus yellows. Also, several hundred seedlings from diseased plants of *Chenopodium amaranticolor, C. murale* (sowbane or nettle-leaf goosefoot) and *Tetragonia expansa* (New Zealand spinach), remained healthy under greenhouse conditions over extended periods. There is no evidence, therefore, that the type of virus yellows found in the United States is seed-transmitted and it may be assumed that new plantings of sugar beet are free of virus yellows until the disease is carried to them by aphids from other plants which have harbored the virus.

**Transmission by Contact.** Kassanis (4) reported transmission of virus yellows in England by rubbing juice from diseased plants over the surface of leaves of healthy plants. The first evidence of infection was small yellow or necrotic spots on the rubbed leaves. Often this was followed by production of typical symptoms on the noninoculated leaves and the plants became systemically infected. Extensive tests at Riverside, California, have given results similar to those obtained in England from inoculation of sugar beet plants with juice from diseased plants. However, infection has occurred in only a low percentage of the inoculated plants and it seems evident that sugar beet is very resistant to infection by inoculation with juice from diseased plants. This resistance is so great that it seems probable that transmission of the disease by contact or by any of the cultural operations employed in growing the crop is very rare, if it occurs at all.

**Transmission by Aphids.** The most important and probably the only agents of transmission of virus yellows are various species of aphids or plant lice. The disease has been transmitted experimentally by means of *Myzus persicae* (green peach aphid), *Aphis rumicis* (bean aphid), and *Macrosiphum solanifolii* (potato aphid). All of these aphids feed on sugar beet but the green peach aphid probably accounts for the greatest amount of spread of virus yellows. On beet, this aphid not only is usually more abundant but it appears also to be a more efficient agent of transmission than either of the other two species. Its relative ability to transmit virus

is indicated by results of tests in which green peach aphids and bean aphids were taken from the same diseased sugar beet leaf and caged singly on seedling sugar beets. In three tests, involving 40 aphids of each species in each test, the peach aphid infected 27, 27 and 19 plants, respectively, whereas the bean aphid infected only 2, 5 and 2 plants, respectively. Similar tests with the potato aphid indicate that it also is less efficient than the peach aphid as a vector of the yellows virus.

The green peach aphid is a highly efficient agent of transmission of the disease. It can pick up virus by feeding 5 to 10 minutes on infected plants and it can acquire a maximum charge of virus in feeding periods of from 6 to 12 hours. After virus is acquired this aphid can transmit it to healthy plants in a feeding period of 5 to 10 minutes. Aphids retain virus for periods of at least 24 to 48 hours after feeding on diseased plants. Thus, aphids not only pick up virus by feeding only a short time, but they also retain the virus long enough to enable winged forms to carry it considerable distances.

In California sugar beets remain alive and grow throughout the year. In nearly all sections where sugar beets are produced commercially, infected plants are available from which virus yellows may spread to new plantings. In all probability beets are the chief source of virus spread. Although a number of weed plants are known to be susceptible to infection, none of these is believed to be an important source of virus. In all instances in which weeds have been found infected extensively, evidence indicates that spread was from sugar beet or spinach to the weed host rather than in the reverse direction.

Beets which serve as sources of infection are of various kinds. The chief sources in California appear to be the following:

1. Some roots always are left in the field at harvest time. Many of these may sprout later and serve as sources of yellows spread. If the beet crop is followed by a noncultivated crop such as alfalfa these beet plants may serve as virus sources for several months.

2. In some areas beets are not harvested in the fall, particularly in wet seasons, but are carried through the winter and harvested the following spring. Such fields can be sources of widespread infestation of new winter and spring plantings in adjacent areas.

3. Fields of beets planted in December and January usually produce a certain number of bolters which mature seeds before harvest. Seeds from these plants fall to the ground and soon germinate if sufficient soil moisture is available. Numerous seedlings of this type, many infected with virus yellows, have been found in early December in cover crops which were planted after the beets were harvested.

4. Beets escape from cultivation and grow along ditch banks, fences, and other uncultivated places. Many of these become infected with virus yellows and may provide a plentiful supply of virus for infection of neighboring beet fields.

5. Wild perennial beets are prevalent in certain areas of central California. Many of these are infected and no doubt they are important sources of spread locally.

In certain parts of central California these sources of infection are so abundant that yellows spreads to entire fields when the plants are young and the fields, as a result, develop a uniform yellowing beginning in May or early June.

## Control Measures

One of the most obvious control measures for virus yellows is elimination of sources of infection for new plantings. In those areas where sugar beets and closely related plants ordinarily donot live in the field through the period between harvest of one crop and planting of the next, elimination of sources of infection usually does not present a serious problem. In those areas in which beets grow throughout the year control by this method is more difficult and in many areas it is impractical under present methods of sugar beet production.

Sprays which drastically reduce aphid populations may reduce or delay infection but no evidence is available which indicates that spraying for control of virus yellows is likely to be a profitable practice under most field conditions.

There is evidence of a range of resistance to virus yellows among varieties of sugar beet (2). However, the range of resistance among commercial varieties does not appear to be a very wide one and, at the present time, this difference is not great enough to justify the planting of any particular variety on the basis of its resistance to virus yellows alone. Whether the success obtained in the breeding of sugar beet for resistance to curly top can be repeated for virus yellows, and varieties developed which will be highly resistant to this latter disease, remains to be determined. The fact, however, that there are some differences in resistance among sugar beet varieties lends support to the hope that plant breeders may eventually develop varieties with at least somewhat greater resistance than that possessed by varieties now available.

## Summary

Virus yellows has been reported from nearly all of the principal sugar beet producing areas of the United States. During 1952 and 1953 it was found in all of the areas of California in which sugar beet is grown, except the Imperial and Hemet Valleys.

The disease attacks sugar beet, table beet, fodder beet and their close relatives. It also affects spinach and a number of noncultivated plants.

Virus yellows is spread by the green peach aphid (*Myzus persicae*), the bean aphid (*Aphis rumicis*), the potato aphid (*Macrosiphum solanifolii*), and possibly other aphid species. The green peach aphid is believed to be by far the most important agent of spread because of its wide host range, prevalence, habits of feeding and migration, and its efficiency as a vector of the causal virus. There is no evidence that the disease is seed transmitted. It is difficult to transmit by juice inoculation and there is no reason to suspect that it is spread by contact in ordinary cultural operations.

Chief sources of field infection in California are: 1. Beets which are missed in harvesting and left to grow in the field. 2. Beets which are carried through the winter and harvested the following spring. 3. Seedlings from seeds which fall from bolters. 4. Escaped beets in non-cultivated and cultivated areas. 5. Wild beets.

No completely satisfactory control measures are available for areas where the disease is most prevalent. There is some hope, however, that it may be possible to increase the resistance of commercial varieties, to some degree at least, by selection and breeding.

## Literature Cited

(1) COONS, G. H.
1952. Virus yellows of beet in the United States. Plant Dis. Reporter 36:356-363.

(2) COONS, G. H.
1953. Resistance of sugar beets to virus yellows. (Abst.) Phytopath. 43:405.

(3) COONS, G. H., and KOTILA, J. E.
1951. Virus yellows of sugar beet and tests for its occurrence in the United States. (Abst.) Phytopath. 41:559.

(4) KASSANIS, B.
1949. The transmission of sugar-beet yellows virus by mechanical inoculation. Ann. Appl. Biol. 36:270-272.

# Effect of Virus Yellows on Yield and Sucrose Content of Sugar Beet in Tests at Riverside, California

C. W. Bennett, Charles Price and Glenn E. Gillespie[1]

Virus yellows of sugar beet was first recognized in Europe a number of years ago and it is now considered one of the most destructive diseases of that crop in that part of the world. Damage is reported to depend to a large degree on the age of the plants at the time of infestation and reduction in yield is more or less proportional to the length of time the plants are diseased. If infestation occurs by the end of June losses may reach 50 percent or more (1, 2)[2]. If infection takes place late in the season losses may be negligible.

Little evidence is available at this time regarding losses being caused by virus yellows in the United States. Undoubtedly virus yellows causes some reduction in yield in those areas where most of the plants are infected early in the season. However, thus far, yields have not indicated that the damage is as severe as that reported from Europe.

Experimental determination by plot technique of the damage virus yellows is capable of producing on sugar beet is not easily accomplished under most field conditions. The disease is spread largely by the green peach aphid, *Myzus persicae*, which is one of the most widely distributed and abundant of aphid species. In most areas where the sugar beet is grown the populations of this aphid are high enough to cause appreciable amounts of spread throughout the season. Even frequent applications of sprays have not been wholly effective in preventing spread. In most cases, therefore, it has been impossible to maintain check plots free of disease to serve as a measure of the reduction in yield in plots inoculated with virus yellows.

It has been observed that in certain inland areas of southern California aphid populations on sugar beet drop to very low levels during the hot dry weather of summer. It was thought, therefore, that it might be feasible to conduct virus yellows tests in such areas with a minimum of spread of disease from inoculated to check plots, if the planting date were delayed until the spring populations of aphids were reduced by parasites, predators and other factors. To test this hypothesis, an experiment was set up on the grounds of the Citrus Experiment Station of the University of California at Riverside, Calif., the spring of 1953 to determine whether more reliable evidence could be obtained regarding the damage virus yellows is capable of producing on sugar beet.

The land used for this experiment had been planted with sugar beet alternated with a cover crop and fallow for a number of years. To maintain the fertility of the soil at a high level a liberal amount of fertilizer is

---

[1] Principal Pathologist, Agronomist and Agricultural Aid, respectively, U. S. Dept. of Agriculture, Riverside, California.

[2] Numbers in parentheses refer to literature cited.

necessary. An application of a 16-20-0 fertilizer was made at a rate of 250 pounds per acre before planting and an application of ammonium nitrate at the rate of 440 pounds per acre was made after thinning.

The experimental field was planted April 29 after aphid populations were reduced to low levels in beet fields in the area. Plants were thinned May 22 and the field was divided into 30 plots, each plot consisting of 4 rows of beets each 50 feet long. Half of the plots were selected by random-choice technique and inoculated with virus yellows June 22 and 23.

Plots 1 to 8, inclusive, were inoculated with aphids in small leaf cages clipped on the tip of a leaf on each plant. In plots 6, 7, and 8 the aphids were caged on plants during the middle of the day when the temperature was very high and the humidity very low and, undoubtedly, a great many of the aphids died before feeding. This accounts for the relatively low infection in these plants (Table 1). Plots 9 to 15, inclusive, were inoculated by placing a piece of diseased beet leaf, with about 10 aphids, on each plant. Under the conditions prevailing at the time, the aphids crawled from the diseased pieces of leaf to the healthy plants within a few minutes.

The source of virus for these inoculations was potted beet plants infected with a virus selection which caused relatively severe symptoms on sugar beet under greenhouse conditions.

All plants, including the checks, were sprayed with a systemic insecticide the day following inoculation and at 14-day intervals through August.

Tips of full-grown leaves of many of the inoculated plants began to turn yellow 1 5to 20 days after inoculation and yellowing increased in in-

**Table 1.—Effect of Virus Yellows on Yield and Sucrose Content of Sugar Beet in Tests at Riverside, Calif., in 1953.**

| Inoculated Plots | | | | | Noninoculated (Check) Plots | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Plot No. | Plants Infected | Sucrose | Yield of Beets per Acre | Yield of Sucrose per Acre | Plot No. | Plants Infected | Sucrose | Yield of Beets per Acre | Yield of Sucrose per Acre |
| | Percent | Percent | Tons | Tons | | Percent | Percent | Tons | Tons |
| 1 | 91.8 | 14.20 | 13.584 | 1.920 | 16 | 1.4 | 13.65 | 22.229 | 3.034 |
| 2 | 93.1 | 14.95 | 15.313 | 2.289 | 17 | 2.0 | 13.90 | 25.439 | 3.536 |
| 3 | 92.9 | 15.30 | 18.277 | 2.796 | 18 | 3.5 | 16.20 | 26.427 | 4.281 |
| 4 | 84.4 | 16.25 | 12.843 | 2.087 | 19 | 0.8 | 15.65 | 30.132 | 4.716 |
| 5 | 70.4 | 15.15 | 17.042 | 2.582 | 20 | 1.5 | 16.35 | 34.331 | 5.613 |
| 6 | 16.1 | 16.10 | 27.415 | 4.414 | 21 | 2.0 | 13.05 | 26.674 | 3.481 |
| 7 | 15.6 | 14.80 | 21.735 | 3.217 | 22 | 0.7 | 15.05 | 29.144 | 4.386 |
| 8 | 32.0 | 16.45 | 19.759 | 3.250 | 23 | 4.7 | 16.55 | 29.885 | 4.946 |
| 9 | 91.3 | 15.25 | 19.265 | 2.938 | 24 | 0.7 | 16.10 | 30.625 | 4.931 |
| 10 | 79.3 | 14.95 | 18.771 | 2.806 | 25 | 0.7 | 16.05 | 32.108 | 5.153 |
| 11 | 57.6 | 12.00 | 23.958 | 2.875 | 26 | 3.1 | 16.20 | 25.439 | 4.121 |
| 12 | 94.7 | 16.10 | 15.807 | 2.545 | 27 | 2.0 | 16.35 | 30.132 | 4.926 |
| 13 | 85.6 | 16.60 | 19.018 | 3.157 | 28 | 2.1 | 15.35 | 30.132 | 4.625 |
| 14 | 90.9 | 15.80 | 17.042 | 2.693 | 29 | 0.0 | 15.45 | 33.343 | 5.151 |
| 15 | 94.6 | 14.60 | 21.241 | 3.101 | 30 | 0.7 | 13.75 | 26.180 | 3.600 |
| Average | | 15.23 | 18.738 | 2.845 | Average | | 15.31 | 28.815 | 4.433 |

tensity during the next two or three weeks. Some of the leaves developed yellow areas often distinctly delimited by larger lateral veins others were more or less uniformly yellow. No evidence of symptoms was observed on any of the younger leaves of the plants. These usually remained green until they were full-size and then began to turn yellow at the tips. Yellowing progressed downward as the leaves became older.

By July 21 the inoculated plots were clearly outlined as yellow spots visible for a considerable distance. The check plots remained green, except for an occasional yellow plant. Striking contrast between inoculated and check plots continued to be evident throughout the season but color differences tended to be less marked toward the end of the season.

Counts of diseased plants were made July 21, August 18, and October 13. Only the results of the counts made October 13 are shown in Table 1 but these results do not differ appreciably from those obtained from the other two counts. There was evidence of very little spread during the season; apparently practically all of the infection which occurred resulted from aphids introduced into the field from the greenhouse at the time of inoculation of the plots. The fact that the incidence of disease in the rows of check plots adjacent to diseased plots was no greater than that in the middle rows of the check plots supports the conclusion that there was very little disease spread during the season. The sharp color difference between an inoculated plot and an adjacent noninoculated plot is shown in Figure 1.

**Figure 1. Plots of sugar beet in test to determine injury produced by virus yellows. Left, 4-row plot inoculated with virus yellows. Right, 4-row check plot free of disease. Photographed 60 days after plot at left was inoculated with virus yellows.**

Infection in the check plots varied from none to 4.7 percent as shown in Table 1, whereas infection in the inoculated plots, except in plots 6, 7, and 8 in which most of the aphids used to inoculate the plants probably died before feeding, varied from 57.6 to 94.7 percent.

The plots were harvested November 3, 4, and 5. Yields are shown in Table 1. Yields per acre were calculated on the basis of total weight of beets in the middle two rows of each plot. Sucrose percent shown is the average of two 10-beet samples taken at random from the middle two rows of each plot.

The results show a rather wide range of variation in both tonnage and sucrose percent among check plots and also among inoculated plots, which no doubt reflects a marked lack of uniformity in the soil used for this experiment. Despite these variations, however, the effect of virus yellows in reducing yield of sugar beets is marked. Indicated reduction in weight of roots is 10.077 tons per acre and of sucrose 1.588 tons per acre or a reduction of 34.9 percent in weight of roots and 35.8 percent in sucrose per acre. The least significant difference at the 5 percent level is 2.775 tons of roots per acre and .507 tons of sucrose per acre, which shows that the results obtained are highly significant. The difference of .08 percent in sucrose in favor of the check plots is not significant statistically. Losses due to yellows in this test, therefore, appear to have been due almost entirely to reduction in weight of root.

This evidence indicates clearly that virus yellows, as it occurs in the United States, is capable of causing severe damage to sugar beet. However, the reductions in yield indicated in these tests probably are greater than those which occur under average conditions in commercial fields. These plots were planted somewhat later than is normal for the district and the plants were infected when relatively small. Both of these factors may have tended to increase the severity of the disease. Also, these plants were inoculated with a strain of yellows virus that, according to greenhouse tests at least, is more virulent than those commonly encountered under field conditions.

There is much evidence indicating that in general the strains of virus yellows prevalent in the United States are less virulent than those widely distributed in Europe.

Losses to be expected from virus yellows in the future may depend, in part at least, on prevalence and distribution of the more virulent forms of virus. It is reported that there is some evidence that the more virulent strains of the yellows virus have tended to become the dominant ones in Europe. Whether this will be true with strains in the United States remains to be determined. In any event, it seems probable that virus yellows may prove to be a disease of major importance in sugar beet production in the United States particularly in those areas in which sufficient numbers of diseased plants are available to serve as sources for early and extensive infection in each succeeding crop.

## Literature Cited

(1) WATSON, D. J., and WATSON, MARION A.
1953. Comparative physiological studies on the growth of field crops. III. The effect of infection with beet yellows and beet mosaic viruses on the growth and yield of the sugar-beet root crop. Ann. Appl. Biol. 40:1-37.

(2) WATSON, MARION A.
1942. Sugar-beet yellows virus. A preliminary account of experiments and observations on its effect in the field. Ann. Appl. Biol. 29:358-365.

# An Alternaria Leaf Spot of the Sugar Beet

J. S. McFarlane, Roy Bardin and William C. Snyder[1]

A hitherto unreported disease of the sugar beet, *Beta vulgaris* L., incited by a parasitic species of Alternaria was found on a sugar beet inbred line at Salinas, California, in January, 1950. The disease has continued to reappear on one or more inbred lines grown at the same location in the Salinas Valley during the past 3 seasons. Although the occurrence of secondary or saprophytic Alternarias, usually *Alternaria tenuis* Auct., has been reported (1, 5)[2] on both sugar beet and table beet, this is the first occurrence in the writers' knowledge of a pathogenic form on this host. This paper reports studies made on the Alternaria disease, and its incitant.

## Symptoms

The disease first appears on the older leaves as dark brown, circular to irregular spots measuring 2 to 5 mm. The spots enlarge as they become older and may reach a diameter of 10 mm. The centers turn gray with age and may become slightly zonate (Figure 1), giving a target spot effect to the lesion. The dead centers may later tear and partially drop out. A reddish coloration may or may not occur around the edges of the older spots, depending on the variety of sugar beet inbred involved.

The spots are frequently delimited by the veins of the leaf, but infections which occur on the veins extend beyond them, on either side. Spotted leaves turn yellow and die prematurely. Under favorable environmental conditions, infection centers are numerous, and the spots coalesce (Figure 1), resulting in a rapid necrosis of the leaf. This necrosis may continue until the leaf blades of the entire plant are almost completely destroyed.

Infection also may occur on the petioles. These are similar to those found on the leaf blade except that they tend to be long and narrow. When cool, wet conditions have continued after the initiation of bolting, lesions have been found on the seed stalks. It seems probable that other organs of the plant may prove to be susceptible also.

During periods of continued high humidity the Alternaria may be seen sporulating sparsely to moderately in the center of the spot. In the case of the leaf infections, sporulation, when it occurs, is usually on the under surface of the leaf.

## Environmental Relations

Infection and disease development occurred at Salinas, California, during the winter months when the mean temperature was 7° to 10° C., and the humidity was high. The earliest observed infection occurred in middle November following a week of cool, rainy weather. The disease was not evident during the rain-free summer months when the mean tempera-

---

[1] Geneticist, Sugar Plant Investigations, Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture; Plant Pathologist, Monterey County Department of Agriculture, Salinas, California; Professor of Plant Pathology, University of California, Berkeley, respectively.

[2] Numbers in parentheses refer to literature cited.

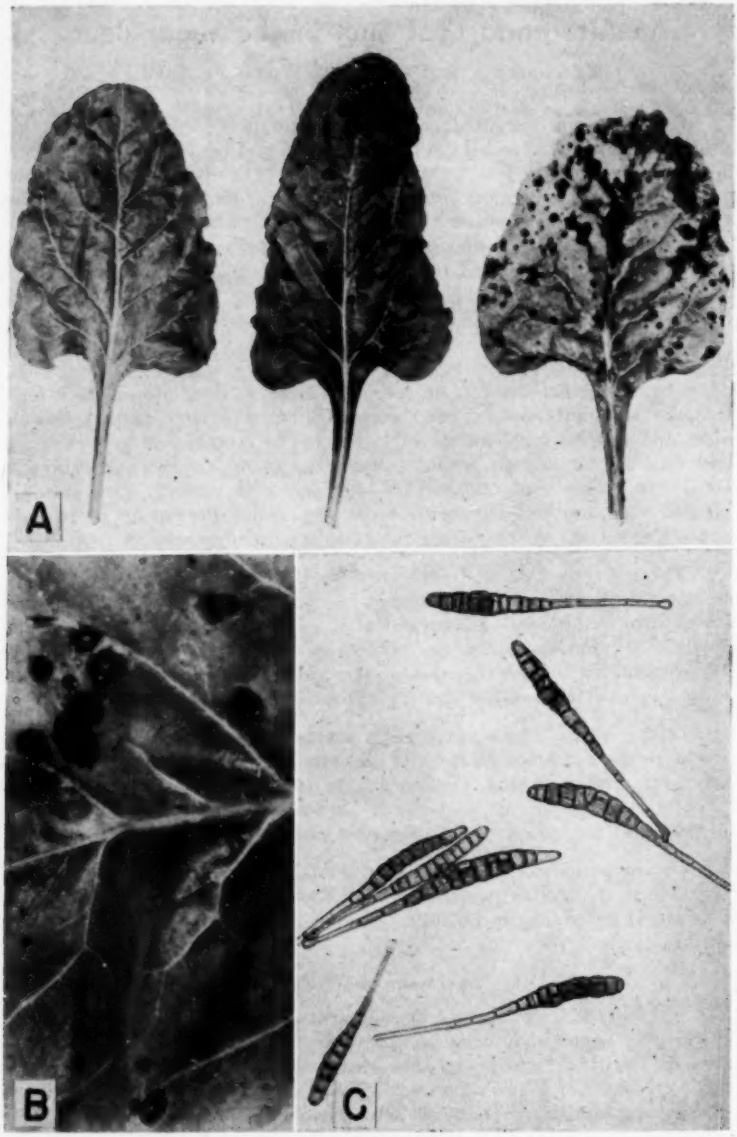


**Figure 1A. Progressive stages of infection with *Alternaria brassicae* on leaves of the CO532 sugar-beet inbred. B. Closeup (natural size) of spots resulting from infection with *A. brassicae*. C. Conidia of *A. brassicae* from beet leaf.**

ture was above 16° C., and the humidity was relatively low. Plants which had been defoliated during the winter produced new growth during the late spring and summer free from infection.

## The Pathogen

The sporulation of the fungus in nature, on the sugar beet and other hosts, is typical of those species treated by Neergaard (2) under the section *Noncatenatae*. The spores are borne singly over the surface of the necrotic portion of the spot, and have long, gradually tapering beaks (Figure 1C). In culture, occasionally short chains of 2 or 3 conidia may occur, or secondary conidia may arise from the sides of the primary ones.

The spore color, septation, approximate size of the spore body and beak and the manner of spore formation agree well with the description given by Neergaard for *Alternaria brassicae* (Berk.) Sacc., and the sugar beet fungus, accordingly, is identified as belonging to that species. Since the species has been well described by Neergaard, no further description of the fungus is required here.

It may be added, however, that *A. brassicae* on sugar beet is readily distinguishable from the ubiquitous *A. tenuis* which abounds on dead or dying plant parts. The spores of the latter fungus occur in long chains (section *Longicatenatae*), and the individual spore is essentially beakless, much smaller in size, the length being one-fourth to one-tenth that of a spore of *A. brassicae*, and dark in color. These several differences are sufficiently distinct to be recognized in the field by means of a hand lens.

*A. brassicae* may be isolated easily from infected tissues by placing the material on straw-water-agar plates (4). When such plates are incubated out-of-doors under conditions similar to those favoring the disease, abundant conidia have been produced with relatively little aerial mycelium, within a week's time.

## Pathogenicity and Host Range

The disease was first observed in 1950 on a sugar beet inbred line designated CO532. During the past three years, two other inbred lines were found to be highly susceptible to *A. brassicae* under field conditions. One of these was a derivative of the U. S. 56 variety and the second was a monogerm inbred line which was developed from a cross between the U. S. 22 variety and the original S. L. C. 101 monogerm inbred described by Savitsky (3).

Artificial inoculations were conducted in the greenhouse to determine the host range of the pathogen. A group of cultivated plants belonging to *B. vulgaris* and a group of plants known to be susceptible to various Alternaria species were included. Inoculation was accomplished by spraying the test plants with a spore suspension from a single spore culture of *A. brassicae* isolated from a leaf of the inbred, CO532. The plants were placed in a humid inoculating chamber maintained at a temperature of 7° to 16° C., for 48 hours. They were then removed and placed in a cool, humid section of the greenhouse to await disease development. Results with susceptible plants are shown in Table 1.

**Table 1.—Pathogenicty of *Alternaria Brassicae* to Various Plants When Artificially Inoculated in the Greenhouse and Naturally Infected in the Field.**

| Plant | Severity of Infection | |
|---|---|---|
| | Greenhouse | Field |
| Eckendorf Red mangel | + | None |
| Golden Tankard mangel | tr | Not tested |
| Detroit Dark Red beet | + | None |
| Green Top Bunching beet | + | None |
| Large Ribbed Dark Green Swiss chard | tr | None |
| U. S. 56/2 sugar beet | tr | tr |
| CO532 inbred | +++ | +++ |
| Copenhagen Market cabbage | + | tr |
| Scarlet Globe radish | +++ | +++ |
| Wild radish | +++ | ++ |

tr—Trace
+—Slight
++—Moderate
+++—Severe

When artificially inoculated under favorable greenhouse conditions, the host range was found to include Eckendorf Red mangel, Golden Tankard mangel, Detroit Dark Red beet, Green Top Bunching beet, Large Ribbed Dark Green Swiss chard, and the U. S. 56 sugar beet variety, all of which belong to *B. vulgaris*. Infection was classed as only a trace or slight on these hosts. Scarlet Globe radish and wild radish, *Raphanus sativus* L., were found to be highly susceptible in the greenhouse. Cabbage (Copenhagen Market) proved to be moderately susceptible. Sporulation occurred on all of these host plants. Carrot spinach, tomato, potato, flax, and zinnia were also inoculated, but no infection occurred.

Plant species which proved susceptible in the greenhouse were also tested in the field. The field planting was made in September, 1953, and infection occurred through natural means. Results are shown in Table 1. Infection took place on fewer plant species in the field than in the greenhouse. The CO532 inbred and Scarlet Globe radish proved most susceptible in this test. Abundant infection occurred on the wild radish but it developed more slowly than on the cultivated radish. A trace of infection was found on the U. S. 56/2 sugar beet variety and on the cabbage.

Wild radish is a common weed in the Salinas area and was found to be severely infected in its native habitat during the late fall and winter months. A culture of *A. brassicae* isolated from wild radish which was growing in the vicinity of the sugar beet trials proved pathogenic on the CO532 inbred and the resulting leaf spot was identical to that produced by inoculation with a culture isolated from a naturally infected leaf of the inbred. An isolate of the fungus obtained from wild radish grown in another part of the Salinas Valley where the susceptible sugar beet inbreds had not been grown also showed the same pathogenicity for CO532.

## Discussion

The regular occurrence of the Alternaria leaf spot on susceptible inbred lines during the past three winters suggests that the fungus is either seedborne or is carried over on other hosts in the area. Attempts to isolate

the pathogen from the seed of susceptible inbreds have been unsuccessful although the disease might potentially be expected to be seedborne if conditions were favorable for infection at seeding time. It is probable that the pathogen is carried over for the most part on crucifers, such as wild radish, which may grow under relatively cool, sometimes foggy conditions in the Salinas area during the summer months.

The host range and pathogenicity studies indicate that the appearance of an Alternaria leaf spot of sugar beets is the result of bringing susceptible inbred lines into contact with an existing pathogen already established on other hosts in the particular area in question. Our present commercial sugar beet varieties as well as several other cultivated crops belonging to the *B. vulgaris* species proved to be resistant or only slightly susceptible in the field. With this disease, the plant breeder needs only to avoid the selection of susceptible varieties rather than to search for resistance, which is the normal procedure in disease-resistance breeding.

The host range as established in the greenhouse included more members of the *B. vulgaris* species than were found susceptible in the field. In the greenhouse the humidity was maintained at a high level at all times and the leaf tissue became water soaked on most plants in the test. This condition may have tended to predispose the greenhouse-tested plants to infection. In the field, conditions favorable for Alternaria infection are also favorable for Ramularia leaf spot and rust infection. The presence of these diseases, together with associated saprophytes made it difficult to identify local infections from *A. brassicae*. It is, therefore, possible that plants which showed only slight infection in the field were overlooked as hosts.

Three different sugar beet inbred lines which were not closely related were found to be highly susceptible. This suggests that genes for susceptibility are widespread within our sugar beet breeding stocks and that the breeder who is developing varieties for fall and winter plantings in the coastal area of California should keep the disease in mind. The inheritance of resistance is under study.

## Summary

An unreported disease of sugar beets caused by *Alternaria brassicae* (Berk.) Sacc., was found on three different sugar beet inbred lines at Salinas, California. During cool, humid weather the disease caused a severe leaf spotting which eventually resulted in the defoliation of the susceptible inbred lines during three successive winters. The host range as determined in both the greenhouse and field is reported. Both wild radish and cultivated radish were found to be preferred hosts. Susceptible crucifers are thought to be the hosts on which the pathogen is carred over from one season to another.

Although our present commercial sugar beet varieties are resistant, the disease does offer a potential danger in that genes for susceptibility exist in some sugar beet germ plasm being used by the breeders.

## Literature Cited

(1) DORN, MARTHA
1950. Untersuchungen uber eine Blattschwarze der Zucherrube. Phytopathologische Zeitschrift 17:85-110.

(2) NEERGAARD, PAUL
1945. Danish specie of Alternaria and Stemphylium. Einar Munksgaard, Copenhagen. 560 pp.

(3) SAVITSKY, V. F.
1950. Monogerm sugar beets in the United States. Proc. Amer. Soc. Sugar Beet Tech. pp. 156-159.

(4) SNYDER, W. C., and H. N. HANSEN
1947. Advantages of natural media and environments in the culture of fungi. Phytopath. 37:420-421.

(5) UNITED STATES PLANT DISEASE SURVEY
1950. Index of plant diseases in the U. S. Special publication No. 1. Part 1:138-142. Mimeographed.

# Methods of Inoculating Sugar Beets with Aphanomyces Cochlioides Drechs[1]

C. L. SCHNEIDER[2]

In the program of breeding sugar beets resistant to *Aphanomyces cochlioides* Drechs., several hundred lines and varieties are tested each year in fields naturally infested with the fungus. In these tests a number of the lines, especially those which are not derived from resistant selections, are found to be very susceptible compared with resistant lines. A quick method of testing the resistance of lines under controlled conditions in the greenhouse would, therefore, be very useful in the breeding program. Since disease exposure in field tests is not always uniform, a method of obtaining artificial localized epidemics in the field would also be very desirable. With these objectives in view, studies were made to develop methods of inoculating sugar beets with *A. cochlioides* in the greenhouse and in the field.

## Greenhouse Tests

### General Methods

In preliminary studies, practically all plants died, and it was not possible to differentiate between resistant and susceptible lines when the inoculum was introduced into the soil before the seedballs were planted. Since it had been reported earlier by Bockstahler and Henderson (2)[3] that the greenhouse reaction of three sugar beet trains corresponded closely to the field determinations when the seedlings were transplanted to soil inoculated with *A. cochlioides*, further studies were made in which inoculum was applied to the soil after the seedlings had emerged. In these tests, plants of resistant and susceptible varieties were grown in flats of autoclaved soil or sand and were inoculated by burying lengths of string on which the fungus had been cultured, between the rows of plants and by pouring a suspension of zoospores along the rows. In both cases, the resistant and susceptible varieties could be differentiated according to differences in number of plants which survived. The zoospore method was chosen for additional tests because it is quicker and easier.

Zoospore inoculum is readily obtained in the laboratory in the following manner, which is an adaptation of a method used by others and reported earlier in a preliminary paper (5):

The fungus is grown for about one week in 250-ml. flasks, each containing a sterile decoction of 5 maize kernels in 50 ml. of tap water. The broth is then decanted from the flasks, and the flasks with the mycelial mats are half filled with sterile tap water. Within 12 to 36 hours the submerged mycelial mats produce large quantities of zoospores, often more than 100,000 per ml., as determined with a haemocytometer. If the spore suspensions are

---

[1] Cooperative investigations of the Field Crops Research Branch, Agricultural Research Service, United States Department of Agriculture, and Minnesota Agricultural Experiment Station. Paper No. 3126, Scientific Journal Series, Minnesota Agricultural Experiment Station.

[2] Assistant Pathologist, Field Crops Research Branch, Agricultural Research Service, United States Department of Agricultrue.

[3] Numbers in parentheses refer to literature cited.

decanted and additional water is added to the flasks, additional crops of spores may be obtained. Temperature is an important factor affecting the production of zoospores in the laboratory. Counts of zoospore suspensions from flasks containing submerged mycelial mats kept for 24 hours at 15°, 20°, 25°, 27.5° and 30° C. indicate that the optimum temperature for zoospore production in the laboratory is near 20° and 25° (Table 1). McKeen (4) previously reported a similar effect of temperature on the time required for the fungus to produce zoospores after immersion of infected sugar beet seedlings in water.

**Table 1.—Influence of Temperature on Number of Zoospores Produced by Mycelial Mats of *Aphanomyces Cochlicides* Submerged in Water for 24 Hours.**

| | Temperature °C. | | | | |
|---|---|---|---|---|---|
| | 15 | 20 | 25 | 27.5 | 30 |
| No. of zoospores per c.c. | 23,000 | 64,000 | 64,000 | 28,000 | 26,000 |

Tests were made to determine the zoospore concentration which would result in the best differentiation between a resistant variety, S. P. 48B3-00, and a susceptible one, S. P. 1-9-00. The plants were grown in 4 inch pots of autoclaved soil at 75° and 85° F. Four suspensions, containing approximately 740, 1,850, 3,700 and 7,400 zoospores per ml. were prepared by diluting a heavy suspension of zoospores obtained from submerged cultures. Two weeks after the plants had emerged, 50 ml. of inoculum were poured into each pot. Counts of surviving plants were made 31 days after inoculation and are presented in Table 2. Under the conditions of this experiment, the lowest concentration, 37000 zoospores per 4 inch pot, was inadequate for differentiating between the resistant and susceptible varieties, as evidenced by the large number of healthy plants of both varieties. It was concluded that a concentration of 100,000 to 200,000 zoospores per pot is needed for differentiating between resistant and susceptible varieties.

**Table 2.—Effect of Number of Zoospores of *Aphanomyces Cochlioides* on Development of Blackroot in Resistant, 48B3-00, and Susceptible, S. P. 1-9-00, Varieties of Sugar Beets Grown at Two Temperatures in the Greenhouse.**

| Number of Zoospores per 4-in. Pot | Average Number of Plants of Each Variety Alive 30 Days After Inoculation[1] | | | |
|---|---|---|---|---|
| | 75° F. | | 85° F. | |
| | S. P. 48B3-00 | S. P. 1-9-00 | S. P. 48B3-00 | S. P. 1-9-00 |
| 370,000 | 6.0 | 2.3 | 7.0 | 0.3 |
| 185,000 | 13.7 | 2.3 | 12.0 | 1.0 |
| 92,500 | 16.0 | 4.7 | 13.0 | 3.7 |
| 37,000 | 22.0 | 20.0 | 12.7 | 9.3 |
| 0 | 21.7 | 22.6 | 22.0 | 24.0 |

[1] Average of 3 replicates.

## Comparison of Greenhouse Reaction with Field Reaction

In a series of two greenhouse tests, 45 lines and varieties which had been included in field tests at East Lansing, Michigan, and Waseca, Minnesota, in 1951 were inoculated with *A. cochlioides*. The plants were grown in 4 inch

pots of autoclaved soil at 75° F. and were inoculated by pouring 50 ml. of a suspension containing approximately 120,000 zoospores into each pot. In the first test, there were 3 pots of each line and in the second there were 5. Except for the resistant and susceptible check varieties, Acc. 1177 and Acc. 1178, respectively, the lines in each test were different.

Counts of surviving plants were made about one month after inoculation. Surviving plants were classified as lightly infected if less than one-fourth of the hypocotyl was discolored and as severely infected if more than one-fourth of the hypocotyl was discolored and reduced to a black thread. Before analyses of variance were made, percentage data were converted to degrees according to Bliss' (13) method from tables in Hayes and Immer (3).

To compare the greenhouse reaction with the field reaction, each line was assigned a numerical rating. In the first test, as shown in Table 3, this rating is the percentage of plants surviving, since this was the way in which the lines differed most. In the second test, the lines differed more on the basis of the percentage of plants which were lightly infected, hence this was the basis of the comparative rating. The field reaction of each line is represented by a numerical rating ranging from 0 (very susceptible) to

**Table 3.—Comparison of Reactions of 45 Sugar Beet Lines Inoculated with *Aphanomyces Cochlioides* in the Greenhouse.**

| | | Test 1 | | |
|---|---|---|---|---|
| | | | Greenhouse Rating[2] | |
| Line | No. of Plants[1] Inoculated | Field Rating | Pct. of Plants: Surviving | Lightly Infected |
| 50A3-0 | 90 | 5.75 | 53.5 | 17.3 |
| EL 1007 | 84 | 5.75 | 39.9 | 16.1 |
| 50A4-00 | 90 | 5.0 | 56.4 | 26.6 |
| 48B3-00 | 90 | 5.0 | 42.3 | 13.6 |
| 48B3-00 | 90 | 5.0 | 42.3 | 13.6 |
| 50A2-00 | 90 | 4.5 | 42.5 | 22.3 |
| Acc. 1174 | 90 | 4.5 | 40.9 | 18.4 |
| Acc. 1170 | 90 | 4.0 | 45.2 | 22.3 |
| Acc. 1179 | 90 | 4.0 | 28.0 | 8.5 |
| 49111-01 | 90 | 3.75 | 36.9 | 6.0 |
| Acc. 1173 | 90 | 3.5 | 35.7 | 18.4 |
| S. L. 944 | 90 | 3.5 | 27.0 | 8.5 |
| 50104-0 | 88 | 3.5 | 31.5 | 10.5 |
| S. L. 1-300 | 90 | 3.25 | 28.2 | 16.1 |
| S. L. 9090H4 | 80 | 2.5 | 19.4 | 0 |
| Acc. 1171 | 90 | 2.5 | 37.7 | 8.5 |
| 49B10-00 | 90 | 2.5 | 35.9 | 15.3 |
| 486-0 | 90 | 2.5 | 31.4 | 10.5 |
| S. L. 944H1 | 90 | 1.25 | 13.1 | 0.0 |
| S. P. 1-9-00 | 68 | 1.0 | 22.2 | 0.0 |
| SL0531-2-4 | 90 | 0.5 | 30.6 | 10.5 |
| S. L. 92H1 | 90 | 0.5 | 18.3 | 0.0 |
| Acc. 1177 | 90 | 5.0 | 45.0 | 20.4 |
| Acc. 1178 | 70 | 1.0 | 20.2 | 0.0 |
| Difference required for significance, odds 19:1 | | | 10.5 | |

(Table continued on page 250)

Table 3 (Continued)

| Line | Test 2 | | Greenhouse Rating[1] | |
|---|---|---|---|---|
| | No. of Plants[1] Inoculated | Field Rating | Pct. of Plants: Surviving | Lightly Infected |
| 50B92-13 | 72 | 7.0 | 78.0 | 58.2 |
| 50B92-25 | 100 | 7.0 | 71.6 | 52.7 |
| 50B4-24 | 100 | 6.75 | 71.6 | 40.3 |
| 50C3-17 | 100 | 6.75 | 90.0 | 49.5 |
| 50B92-26 | 97 | 6.75 | 68.0 | 48.5 |
| 50B92-24 | 96 | 6.75 | 69.2 | 38.5 |
| 50B1-1 | 100 | 6.5 | 64.9 | 34.5 |
| 50B94-33 | 100 | 6.5 | 66.4 | 46.6 |
| 50A7-00 | 93 | 5.0 | 69.0 | 61.2 |
| 50B4-15 | 100 | 5.0 | 67.2 | 31.6 |
| 50B3-0 | 100 | 5.0 | 68.9 | 57.0 |
| 50C3-31 | 100 | 5.0 | 80.0 | 60.5 |
| 50B92-37 | 47 | 5.0 | 81.9 | 41.9 |
| 50B4x33 | 100 | 5.0 | 80.0 | 50.4 |
| 50B3x06 | 100 | 3.25 | 63.4 | 42.1 |
| 50B12-3 | 100 | 3.0 | 60.7 | 34.3 |
| 50B10-3 | 100 | 2.75 | 67.2 | 41.2 |
| 50B57x2 | 100 | 2.5 | 60.7 | 20.6 |
| 50C3-10 | 100 | 2.5 | 57.4 | 28.4 |
| 50B88x2 | 100 | 2.5 | 81.9 | 44.4 |
| 50B69x2 | 72 | 2.25 | 60.9 | 17.6 |
| 483-0 | 44 | 0.0 | 41.4 | 4.5 |
| Acc. 1177 | 97 | 5.0 | 74.4 | 45.5 |
| Acc. 1178 | 96 | 1.0 | 37.8 | 7.3 |
| Difference required for significance, odds 19:1 | | | | 13.1 |

[1] Before inoculation plants were thinned where necessary in order to equalize stands as much as possible.
[2] Expressed as $\sin^2 \Theta$.

7 (very resistant). A rating of 5 means that a line was as resistant as the resistant check variety, Acc. 1177, which was the standard for comparison. Stand, root size and shape, and severity of root rot were criteria used in determining field ratings.

The results of the two tests are presented in Table 3 and are summarized in Table 4. In each of the tests, there were differences betwen varieties in their reaction to the disease. In most cases, the reaction in the greenhouse was similar to that in the field. Because of the heterozygosity of many of the lines, it is believed that precision in evaluating the lines would have been gained by using a larger number of replications.

## Field Tests

Three methods of inoculation were compared in preliminary experiments in the field. Zoospore suspensions were applied to rows of emerging seedlings with a sprinkling can; artificially infested soil was applied with the seed at planting by means of a fertilizer distributor mounted on a Planet Jr. planter; and autoclaved sugar beet seed balls, coated with vermiculite and nutrient broth and artificially infested with the fungus, were applied in the row with the seed with the fertilizer distributor. Infection occurred only when the latter method was used. Stands in inoculated plots were lower

than in noninoculated plots. Also, when sugar beet seedlings were grown in the greenhouse in pots containing soil taken from inoculated field plots one month after the inoculum was applied, most of the seedlings became infected with *A. cochlioides* and damped-off. Most of the seedlings grown in soil taken from adjoining noninoculated plots remained alive.

**Table 4.—Comparison of Black Root Resistance Ratings of 44 Lines of Sugar Beets Assigned on the Basis of Field Tests and Greenhouse Tests.**

| Field Rating Classes | Number of of Lines | Number of Lines in Each Field Rating Class With a Greenhouse Rating: | | |
|---|---|---|---|---|
| | | Greater than Acc. 1177 | Same as Acc. 1177 | Less than Acc. 1177 |
| 7-7.9 | 2 | 0 | 2 | 0 |
| 6-6.9 | 6 | 0 | 6 | 0 |
| 5-5.9 | 10 | 3 | 6 | 1 |
| 4-4.9 | 4 | 0 | 3 | 1 |
| 3-3.9 | 7 | 0 | 2 | 5 |
| 2-2.9 | 9 | 0 | 4 | 5 |
| 1-1.9 | 3 | 0 | 0 | 3 |
| 0-0.9 | 3 | 0 | 0 | 3 |

As these tests were limited in scope they are merely indicative of the possibility of inoculating seedlings by this method. More extensive tests are required before an evaluation can be made of the suitability of this method for obtaining a localized epidemic in the field.

## Summary

1. Methods for growing inoculum and inoculating young sugar beet plants with *Aphanomyces cochlioides* are described.

2. In greenhouse tests, sugar beet lines and varieties differed in their reaction to *A. cochlioides*. In general, the relative degree of resistance of each line or variety tested in the greenhouse was similar to that observed in the field.

## Literature Cited

(1) BLISS, C. I.
1938. The transformation of percentages for use in the analysis of variance. Ohio Jour. Sci. 38:9-12.

(2) BOCKSTAHLER, H. W. and HENDERSON, R. W.
1946. Reaction of sugar beet strains to *Aphanomyces cochlioides*. Proc. Amer. Soc. Sug. Beet Tech: 237-245.

(3) HAYES, H. K. and IMMER, F. R.
1942. Methods of plant breeding. McGraw-Hill Book Co., New York and London.

(4) MCKEEN, W. E.
1949. A study of sugar beet root rot in Southern Ontario. Can. Jour. Res. C. 27:284-311.

(5) SCHNEIDER, C. L. and JOHNSON, H. G.
1952. The production of zoospore inoculum of *Aphanomyces*. Phytopath. 42:18. (Abstract).

# Correlation Between Sugar Beet Crop Losses and Greenhouse Determinations of Soil Infestation by Aphanomyces Cochlioides[1]

H. C. Fink and W. F. Buchholtz[2]

Damping off of seedlings and rot of fleshy roots of sugar beets caused by *Aphanomyces cochlioides* Drechsler is a limiting factor in the production of that crop in many areas of the United States.

*Aphanomyce cochliodes* was described and named by Drechsler in 1928 and 1929 (5, 6)[3], when he found that pathogen causing severe damping off of sugar beet seedlings in Michigan. That the fleshy root as well as the seedling is subject to pathogenesis by *A. cochlioides* was observed in northern Iowa in 1938 by Buchholtz and Meredith (3, 4). Since that time this fungus has been reported as an active pathogen in other sugar beet-producing areas of the United States (1, 7, 8, 10).

The sporadic prevalence of *A. cochlioides* in the Wisconsin drift soils of north central Iowa has been a major factor in the abandonment of sugar beets as a crop in that area. Lack of other adequate control measures prompted consideration of the possibility that heavy crop losses could be avoided by planting in fields not at the time infested with *A. cochlioides*. Such a possibility depends upon successful estimation of soil infestations by *A. cochlioides* and a close correlation of such estimates with crop failures by this fungus.

Such an approach to avoidance of crop depredation by a soil-borne root pathogen is not new to sugar beet culture. Leach and Davey (9) were successful in estimating the sclerotial populations of *Sclerotium rolfsii* Sacc. in soil from the numbers of sclerotia washed and screened from soil samples. Their estimates of sclerotial populations were correlated with relative number of beets infected in the fields sampled. Further use of this method was made in determining fluctuations of populations of viable sclerotia in crop rotation studies.

This paper presents two seasons' results of greenhouse determinations of degrees of infestations by *Aphanomyces cochlioides* in soil samples taken from northern Iowa sugar beet fields and the correlation of degrees of infestation with crop losses and yields in the respective fields.

## Procedures

Determination of degree or intensity of soil infestation by *Aphanomyces cochlioides* for a particular field consisted essentially in growing a stand of

---

[1] Journal Paper Number J-2348 of the Iowa Agricultural Experiment Station, Ames, Iowa, project 449. Taken from a thesis submitted by the senior author to the Graduate Faculty of the Iowa State College in partial fulfillment of requirements for the degree, Master of Science. The assistance of Dr. G. D. Smith, U.S.D.A. and Iowa State College, and Dr. I. J. Nygard, University of Minnesota, in making soil type determinations, and of A. G. Quamme and D. B. Ogden, American Crystal Sugar Co., in locating suitable fields and facilitating observations, is gratefully acknowledged.

[2] Formerly Research Fellow, and Associate Professor of Botany and Plant Pathology, respectively.

[3] Numbers in parentheses refer to literature cited.

sugar beet seedlings in the greenhouse in a soil sample taken from that field and determining how many of the badly diseased seedlings were infected by *A. cochlioides*. Each soil sample was a composite of small samples taken to a depth of six inches. All the soil taken from a field was placed in a new double-layered flour sack, in which it was transported. The soil in each sack was thoroughly mixed before being placed in pots. The potting bench was washed with tap water and a brush before each soil sample was placed upon it.

One pot of soil from each sample was steamed at 15 pounds pressure for four hours and served as a check. As additional checks, five pots of unsteamed greenhouse soil were included. Twenty seed clusters treated with ethyl mercury phosphate (to preclude infection with other damping off fungi (2)) were planted about one-half inch deep in each pot. The pots containing the unsteamed field samples and the greenhouse soil were arranged in five randomized blocks so that each soil sample was represented in each block. The pots containing the steamed samples were arranged in a sixth randomized block.

Total number of seedlings and number of diseased seedlings per pot were recorded daily for 30 days. Each day the diseased seedlings were collected, washed with a camel's hair brush to remove all soil and floated in 10 to 15 cc. of distilled water in sterile petri dishes, one seedling per dish.

Almost without exception, in 24 hours extramatrical mycelium and sporangia of *A. cochlioides* had developed on the seedlings infected by that fungus. *A. cochlioides* was distinguishable from other fungi by the presence of encysted zoospores adhering to the tips of its sporangia. If no *A. cochlioides* had grown from the beet seedlings in 24 hours, or if the identity of other fungi growing from them into the water could not be determined, the seedlings were removed from the water, placed between sheets of filter paper to remove the excess water and transferred to petri dishes containing 2 percent agar. After 24 hours the fungi present could be identified and recorded. In only a very few cases was the presence of *A. cochlioides* recorded after seedlings had been transferred to agar plates.

After 30 days the number of diseased seedlings which yielded growth of *A. cochlioides* was recorded for each soil sample. That number was divided by the total number of seedlings. The resulting quotient was multiplied by 100. The percentage so obtained is the estimated intensity of infestation by *A. cochlioides* for the soil samples. In all future references to this percentage, the term "intensity of soil infestation" will be used in lieu of "percentage of seedlings infected by *A. cochlioides*" or "estimated intensity of soil infestation by *A. cochlioides*."

In 1946, soil samples were collected in the fall from 19 Iowa fields, among which were fields in which there had been no, a few, or many root-rotted beets during the 1946 growing season.

During April, 1947, soil samples were collected from 24 fields in which sugar beets were to be planted that year. All but five of these 24 fields were visited in June, before thinning time. One hundred seedlings were dug

and carefully examined at each of three places per field. Diseased seedlings were taken to the laboratory and the presence of *A. cochlioides* in their tissues were determined by the method described.

During August an estimate of crop loss caused by *A. cochlioides* was made for each field. This estimate was based on stand and relative abundance of beets showing evidence of root rot and was recorded as percentage of crop loss.

In October, 300 beets were dug and topped in each of the 24 fields. The normal shaped beets and those obviously deformed by disease were weighed separately. The percentage of deformed roots, by weight, was calculated for each field.

In an attempt to contribute information on the effect of crop rotation on abundance and effect of *A. cochlioides* in the soil, farmers were asked for cropping histories of the fields from which soil samples were taken. Unfortunately, definite cropping history was available for only half the fields.

Soils in the fields from which soil samples were taken were classified to determine whether the pathogen tends to be prevalent in particular types or classes of soil.

## Results

Two major experiments comprised these investigations. The first, which was somewhat exploratory, consisted of 1. Sampling the soil in 19 northern Iowa sugar beet fields in the fall of 1946 after the crop had been harvested; 2. Estimating the intensity of infestation by *Aphanomyces cochlioides* of each sample according to the method described, 3. Correlating these estimates with previously reported field losses from "root rot."

The second experiment, in 1947, consisted of: 1. Sampling the soil in 24 northern Iowa and southern Minnesota sugar beet fields; 2. Estimating the intensity of infestation of each sample by *A. cochlioides;* 3. Estimating subsequent crop loss in these fields caused by *A. cochlioides;* 4. Weighing 300 beets from each field and determining the percentage of deformed roots (by weight), and 5. Correlating intensities of soil infestation with estimated crop losses, percentage of deformed roots and weights of 300 beets from each field.

The results of these two experiments will be presented separately.

### Reported Crop Losses and Intensity of Soil Infestation, 1946

The intensities of soil infestation by *Aphanomyces cochlioides* in soil samples taken from 19 northern Iowa sugar beet fields in 1946, together with the previously reported crop loss in each field from "root rot," are listed in Table 1. The crop loss reports were those of sugar company field men and farmers, based upon observations made by them during the 1946 growing season.

In all but three cases (fields 4, 8 and 11) the crop loss reported for the field was comparable to the intensity of soil infestation by *A. cochlioides* according to greenhouse and laboratory determinations. In Field 4 the soil

sample was taken from a small portion of the field in which there had been much loss of stand, while the crop loss report was based upon observation of the entire field. In Field 8 the beets were plowed up early in the season after a heavy loss of the stand by damping off, but no *A. cochlioides*-infected seedlings were found in the stand of beets grown in the soil sample collected from that field. In Field 11 the crop was not harvested because the beets failed to reach marketable size. The intensity of infestation by *A. cochlioides* was estimated to be only 11 percent, or light. It should be kept in mind that there was no opportunity to determine the nature of the "root rot" reported as the cause of crop loss in this or any other field in 1946.

### Soil Infestation and Damage in the Field by *Aphanomyces Cochlioides* in 1947

Intensities of infestation by *Aphanomyces cochlioides* in the respective soil samples and estimated crop losses in 24 northern Iowa and southern Minnesota sugar beet fields sampled are presented in Table 2. There was a correlation of 0.926 between estimated crop loss and intensity of soil infestation by *A. cochlioides*. This coefficient is significant at the 1 percent level. The regression of estimated crop loss of intensity of soil infestation was calculated and is expressed in the equation, $Y = 0.786X - 3.09$. This regression line, together with individual observations, is plotted in Figure 1.

The close agreement between greenhouse and laboratory determinations of soil infestation by *A. cochlioides* and the estimated crop losses due to this pathogen is evident. Especially evident is the fact that no losses and heavy crop losses were recorded for fields with no infestations and heavy infestations, respectively. Only possible exceptions were Fields 16 and 17. Cir-

**Table 1.—Intensities of Soil Infestation by *Aphanomyces cochlioides* and Previously Reported Sugar Beet Crop Losses in 19 Northern Iowa Beet Fields, 1946.**

| Field number | Intensity of soil infestation | Reported crop loss |
|---|---|---|
| 1 | 48 | entire crop |
| 2 | 59 | heavy |
| 3 | 0 | none |
| 4 | 81 | light |
| 5 | 4 | light |
| 6 | 46 | entire crop |
| 7 | 2 | none |
| 8 | 0 | entire crop |
| 9 | 0 | light |
| 10 | 0 | none |
| 11 | 11 | entire crop |
| 12 | 1 | none |
| 13 | 0 | none |
| 14 | 0 | light |
| 15 | 29 | entire crop |
| 16 | 32 | entire crop |
| 17 | 0 | none |
| 18 | 39 | entire crop |
| 19 | 0 | none |
| Greenhouse soil | 0 | ..... |

cumstances pointed to an underestimation of loss in Field 17; about half of the field had been plowed up at thinning time because of a very poor stand, cause of which was not ascertained. Loss was estimated for the portion of the field not destroyed.

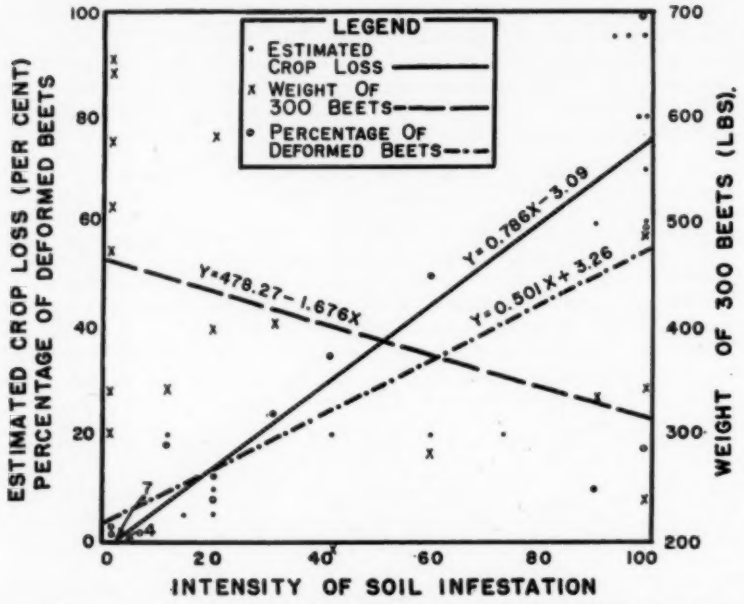


**Figure 1.—Regression of estimated crop losses, weight of 300 beets and percentage of deformed beets on intensity of soil infestation by *Aphanomyces cochlioides*.**

Isolations were made from ten or more diseased seedlings taken from each of 19 fields in June. In twelve cases where soil infestation by *A. cochlioides* was detected in the greenhouse and a laboratory, the fungus was recovered from seedlings collected in the fields from which the infested soil samples were taken. In seven cases where no *A. cochlioides* was detected in the soil samples by greenhouse test, it was absent in seedlings collected from the respective fields. Fields 15, 16, 17 and 18 were not visited in June; the beets in Field 24 had been destroyed.

Percentages of deformed roots, by weight, and weights of 300 beets harvested from each of 17 fields are also presented in Table 2.

The correlation between percentage of deformed roots and intensity of soil infestation by *A. cochlioides* was found to be 0.730. This coefficient is significant at the 1 percent level. The regression of percentage of deformed roots on intensity of soil infestation was calculated and is expressed by the

equation, Y = 0.501X + 3.26. This regression line, together with individual observations, is plotted in Figure 1. In field 5 the percentage of deformed roots was found to be only 16 percent, while the intensity of soil infestation was determined to be 99. A low percentage of deformed roots in relation to soil infestation was also recorded for Field 15. In these two fields, especially in Field 15, the total weight of 300 beets was low in comparison to fields in which the intensity of infestation was low or zero. Small beet size, rather than deformed roots, may have been the principal effect of *A. cochlioides* infestation in these fields.

**Table 2.—Intensities of Soil Infestation by *Aphanomyces cochlioides*, Estimated Crop Losses, Percentages of Deformed Roots and Weights of 300 Beets in 24 Northern Iowa and Southern Minnesota Beet Fields, 1947.**

| Field number | Intensity of soil infestation | Estimated crop loss % | Deformed roots % | Weight 300 beets lbs. |
|---|---|---|---|---|
| 1 | 93 | 95 | .... | ..... |
| 2 | 0 | 0 | 0 | 479 |
| 3 | 0 | 0 | 0 | 302 |
| 4 | 0 | 0 | 3 | 666 |
| 5 | 99 | 60 | 16 | 490 |
| 6 | 100 | 80 | .... | ..... |
| 7 | 15 | 5 | .... | ..... |
| 8 | 12 | 20 | 19 | 348 |
| 9 | 0 | 0 | 2 | 347 |
| 10 | 0 | 0 | 1 | 515 |
| 11 | 31 | 20 | 24 | 405 |
| 12 | 0 | 0 | 0 | 578 |
| 13 | 97 | 95 | .... | ..... |
| 14 | 99 | 70 | 59 | 238 |
| 15 | 90 | 60 | 10 | 340 |
| 16 | 60 | 20 | 51 | 283 |
| 17 | 74 | 20 | .... | ..... |
| 18 | 42 | 20 | 36 | 199 |
| 19 | 0 | 0 | 0 | 659 |
| 20 | 100 | 95 | .... | ..... |
| 21 | 20 | 5 | 13 | 572 |
| 22 | 20 | 10 | 8 | 405 |
| 23 | 99 | 80 | 100 | 346 |
| 24 | 2 | [1] | .... | ..... |
| Greenhouse soil | 0 | | | |

[1] Note: The beets in Field 24 were destroyed before thinning time in June.

The correlation between weight of 300 beets and intensity of soil infestation by *A. cochlioides* was found to be —0.473. This coefficient is significant at the 5 percent level. No data concerning soil fertility, soil moisture or thinning dates were compiled. The regression of weight of 300 beets on intensity of soil infestation is expressed by the equation, Y = 478.27 — 1.676X, and this regression line, together with individual observations, is also plotted in Figure 1.

It seems apparent that there was a positive relationship and highly significant correlation between reported and estimated crop losses and intensities of soil infestation by *A. cochlioides* according to greenhouse deter-

minations in 1946 and 1947, respectively. In the 1947 experiment, percentage of deformed roots and lack of beet size were also correlated with soil infestation.

### Soil Acidity and *Aphanomyces cochlioides* Infestation

Acidity (pH) was determined for each soil sample. There obviously was no relationship between pH and the intensity of infestation by *Aphanomyces cochlioides*, estimated crop loss, percentage of deformed beets or weight of a sample of 300 beets.

### Crop Rotation and *Aphanomyces cochlioides* Infestation

For twelve fields, the crops grown one, two or three years prior to the 1947 sugar beet crop were ascertained and recorded, but no significant relationship was evident from such records.

### Soil Type and *Aphanomyces cochlioides* Infestation

Soil types in all but one of the fields from which soil samples were taken in 1947 and relative intensities of *Aphanomyces cochlioides* infestation in the samples are recorded in Table 3. No soil type included was

**Table 3.—Soil Types in 23 Fields from Which Samples Were Taken in 1947 and Relative Infestation of Samples by *Aphanomyces Cochlioides*.**

| Field number | Soil type | Relative infestation |
|---|---|---|
| 1 | Floyd | heavy |
| 2 | Floyd | none |
| 3 | Webster-like, over sandy out-wash | none |
| 4 | Webster silt loam and Glenco | none |
| 5 | Webster silt loam and Glenco | heavy |
| 6 | Webster loam—heavy subsoil phase | heavy |
| 7 | Webster and Glenco | light |
| 8 | Clarion, Webster and Glenco | light |
| 9 | Webster loam and Nicolet | none |
| 10 | Webster silt loam | none |
| 11 | Webster silt loam, Nicolet and Glenco | light |
| 12 | Clarion and Webster silt loam | none |
| 13 | Webster loam—heavy subsoil phase | heavy |
| 14 | Webster loam and Glenco | heavy |
| 15 | Clarion, Webster silt loam and Glenco | heavy |
| 16 | Webster and Glenco | heavy |
| 17 | Clarion | heavy |
| 18 | Clarion | light |
| 19 | Webster silt loam | none |
| 20 | Webster loam—heavy subsoil phase | heavy |
| 21 | Webster loam—heavy subsoil phase | light |
| 22 | Clarion and Webster loam | light |
| 23 | Webster silt loam | heavy |

found to be free in all cases, but samples from Webster loam-heavy subsoil phase were heavily infested in three of four cases.

## Summary

The intensities of soil infestation by *Aphanomyces cochlioides* in 19 sugar beet fields in 1946 and in 24 fields in 1947 were determined as follows: A stand of sugar beet seedlings was grown in the greenhouse in a soil sample

collected from each field. The number of diseased seedlings infected by *A. cochlioides* was determined and converted to a percentage, which was recorded as the intensity of infestation of the soil in the field from which the sample was taken.

In 1946 the soil samples were collected after harvest, and the intensity of infestation in each of the 19 fields was comparable to the previously reported crop loss from "root rot" in that field.

In 1947 the soil samples were collected from 24 fields before beets were planted in the spring. The estimated intensities of soil infestation by *A. cochlioides* were significantly correlated with: 1. estimated crop losses; 2. percentages of deformed roots, and 3. weights of 300 beets harvested in these fields.

These results indicate that intensity of infestation by *A. cochlioides*, or lack of infestation, of the soil in a particular field can be determined successfully and that such determination can be useful in selecting fields in which *A. cochlioides* will not be the cause of sugar beet crop failure.

## Literature Cited

(1) AFANASIEV, M. M.
1946. Fungi causing diseases of sugar-beet seedlings in Montana. (abstr.) Phytopath. 36:394.

(2) BUCHHOLTZ, W. F.
1944. The sequence of infection of a seedling stand of sugar beets by *Pythium debaryanum* and *Aphanomyces cochlioides*. Phytopath. 34:490-496.

(3) BUCHHOLTZ, W. F., and MEREDITH, C. H.
1938. A sugar-beet root rot caused by *Aphanomyces cochlioides* (abstr.) Phytopath. 28:4.

(4) BUCHHOLTZ, W. F., and MEREDITH, C. H.
1944. Pathogenesis of *Aphanomyces cochlioides* on taproots of the sugar beet. Phytopath. 34:485-489.

(5) DRESCHSLER, C.
1928. The occurrence of *Aphanomyces cochlioides* n. sp. on sugar beets in the United States. (abstr.) Phytopath. 18:149.

(6) DRESCHSLER, C.
1929. The beet water mold and several related root parasites. Jour Agr. Res. 38:309-361.

(7) KOTILA, J. E., and COONS, G. H.
1940. Aphanomyces root rot of sugar beet as influenced by phosphate application. Proc. Amer. Soc. Sugar Beet Tech. 1940:223-225.

(8) LEACH, L. D.
1945. Sugar beet diseases. Spreckels Sugar Beet Bul. 9:1-8.

(9) LEACH, L. D., and DAVEY, A. E.
1932. Determining the sclerotial population of *Sclerotium rolfsii* by soil analyses and predicting losses of sugar beets on the basis of these analyses. Jour. Agr. Res. 56:619-631.

(10) TERVET, IAN W.
1943. Plant disease surveys in Minnesota and the Dakotas. Pl. Dis. Rptr. 27:373-375.

# Field Trials With Soil Row Treatment for the Control of Damping-off of Sugar Beets

TORREY LYONS, L. D. LEACH AND F. J. HILLS[1]

In greenhouse experiments, chemical soil-row treatments have given good control of sugar beet seedling diseases caused by three of the four pathogens principally responsible for these diseases in California (1)[2]. Results were usually favorable when *Pythium ultimum*, Trow, *P. aphanidermatum* (Eds.) Fitsp., and *Rhizoctonia solani* Kuhn were the pathogens involved, but the treatments were not very effective in controlling attacks of *Aphanomyces cochlioides* Drech.

In order to obtain information as to the effects of soil-row treatments under field conditions, several field trials were conducted in 1953. This paper reports the results of these trials.

## Procedure

For simplification, a single fungicide at a single rate of application was used in each trial. Captan (N-trichloromethylmercapto-4-cyclohexene-1, 2-dicarboximide) was used in most of the experiments. Several greenhouse trials had shown this material to be as effective as others in controlling the various pathogens.

Fields in which damping-off had destroyed the first planting or fields with severe damping-off history were selected for the trials. To obtain information on the pathogens involved, soil was collected at the site of each trial at the time of planting. The soil sample representing each trial was made up of sub-samples taken from the center of each replication. Sugar beets of the variety U. S. 41 were grown in this soil in flats inthe greenhouse. Diseased seedlings were diagnosed in water culture. Soil reaction and total salt content of each soil sample were also determined.

The fungicide in the field trials was applied with equipment designed and built by R. Kepner of the Department of Agricultural Engineering, University of California, Davis. This equipment consists of a five-gallon pressure tank containing an agitator mounted on a platform which can be clamped on a planter. Rubber hoses lead from the outlet valves to one or two fan-type spray nozzles clamped behind each planter shoe.

Two nozzles were used to deliver the fungicide to each row when planter construction allowed sufficient room. One spray fan was directed downward, slightly diagonal to the row, to cover the seed and sides of the open furrow. The second spray fan was set parallel with the row, and directed on the soil closing the seed furrow.

If only one nozzle was used, the spray fan was set diagonal to the seed furrow and directed to cover the seed and sides of the open furrow.

---

[1] Farm Advisor, Plant Pathologist, and Extension Agronomist, respectively, University of California, Davis, California.

[2] Numbers in parentheses refer to literature cited.

Pressure used was approximately twenty-five pounds per square inch and was provided by connecting a five-pound $CO_2$ bottle with pressure regulator valve into the tank.

An attempt was made to apply 2 pounds per acre (based on a 20-inch row spacing) of actual captan using a formulation of a wettable powder containing 75 percent captan. The actual dosage delivered, however, varied between trials from 1.9 to 2.9 pounds per acre due to different pressures and planter speeds. Arasan S. F. (75 percent tetramethylthiuram disulphide) was used in trial 8 at 1.4 pounds of active ingredient per acre.

Approximately 25 gallons of water per acre was applied if one nozzle was used, and 50 gallons if two nozzles were used.

Most of the field trials consisted of eight replications of paired plots. Each plot was 4 rows wide and 50 to 100 feet in length. Treated and non-treated plots were planted with the same planter shoes. Treatment effects were evaluated by counting total seedlings in the center 100 inches in each row of each plot. Two seedling counts were made in each trial, one shortly after emergence was complete to reflect total emergence, and another just before thinning to evaluate the effect of the treatment on seedling survival. It should be noted that trial 4 was established when the field (including trial 3) was replanted, the initial stand having been destroyed by damping-off organisms.

## Results and Discussion

The emergence and survival of sugar beet seedlings grown in the greenhouse in soil from the location of each field experiment are shown in Table 1. Table 2 indicates the pathogens involved in these flats of soil as deter-

**Table 1.—Emergence and Survival of Seedlings in Greenhouse Flats of Soil from Sites of Field Experiments. Values Given Are Seedlings per 40 Seed Units.**

| Treatment | Trial Number 1 | 2 | 3 and 4[1] | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| **Emergence—13 days after planting** | | | | | | | |
| Non-treated | 10 | 25 | 15 | 10 | 14 | 24 | 20 |
| Phygon seed treatment[2] | 43 | 36 | 27 | 50 | 48 | 37 | 45 |
| **Survivors—13 days after planting** | | | | | | | |
| Non-treated | 0 | 16 | 2 | 3 | 6 | 5 | 3 |
| Phygon seed treatment[2] | 29 | 29 | 12 | 50 | 37 | 9 | 18 |

[1] Trials 3 and 4 were conducted on the same area, No. 4 being established when the field was replanted.
[2] .25 gms. Phygon in suspension sprayed on 100 gms. of seed.

**Table 2.—Water Culture Diagnosis of Diseased Seedlings from Flats of Field Soil. Values Given Are Percent of Total Seedlings Diagnosed.**

| Pathogen | Trial Number 1 | 2 | 3 and 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| Pythium ultimum | 78 | 100 | 18 | 17 | 3 | 30 | 83 |
| P. aphanidermatum | 0 | 0 | 18 | 5 | 0 | 0 | 0 |
| Rhizoctonia solani | 11 | 0 | 0 | 78 | 97 | 30 | 8 |
| Aphanomyces cochlioides | 11 | 0 | 64 | 0 | 0 | 40 | 9 |
| Total seedlings diagnosed | 27 | 7 | 22 | 18 | 29 | 30 | 210 |

mined by water culture diagnosis of diseased seedlings. The effects of soil-row treatment on seedling emergence and survival in the 8 field trials are given in Table 3.

**Table 3.—Effect of Soil-Row Treatment on Damping-off of Sugar Beet Seedlings in Field Trials. Values Given Are the Number of Seedlings per 100 Inches and Are Means of Eight Replications.[1]**

| Treatment[2] | Trial Number 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| | | | | Emergence | | | | |
| Non-treated | 38 | 92 | 19 | 9 | 118 | 95 | 154 | 76 |
| Treated | 38 | 105[5] | 23 | 10 | 130[5] | 100 | 158 | 95[4] |
| | | | | Survivors | | | | |
| Non-treated | —[7] | 50 | 9 | 5 | 92 | 70 | 102 | 39 |
| Treated | —[7] | 57 | 20[4] | 6 | 104[6] | 74 | 139[4] | 51[3] |

[1] Trial 8 consisted of six replications.
[2] Captan was the fungicide used in trials 1-7 and Arasan SF in trial 8.
[3 4] Indicate F values exceeding the 5 percent and 1 percent levels of significance respectively.
[5] Observed F 4.30, required F at the 5 percent level 5.99.
[6] Observed F 4.47, required F at the 5 percent level 5.99.
[7] The trial was thinned before a survival count was made. A count of 28 skips over 12 inches per 100 feet of row was obtained in both non-treated and treated plots.

In three of the trials (trials No. 3, 7 and 8) soil-row treatments significantly increased the number of surviving seedlings. In one other trial (trial 2), a significant improvement in seedling emergence was observed which might have resulted in a measurable improvement in numbers of surviving seedlings had not a mechanical thinner gone over the area before survival counts were made. In only one of the above 4 trials, however (trial 3), was the loss of seedlings in check plots great enough to result in a stand failure. In this case, soil-row treatment gave sufficient protection to preserve enough seedlings for a commercially acceptable stand.

In trials 1, 5 and 6, significant treatment differences were not observed, and satisfactory stands were obtained without row treatment.

It is interesting to note that row treatment was quite effective in controlling severe damping-off in trial 3, but failed to do so when this field was replanted (trial 4). Satisfactory explanation for success of the row treatment in the first planting and failure in the second cannot be given from the data available. One possible explanation, however, in the light of previous greenhouse trials (1) is that under the cooler and drier environmental conditions of the first planting, attack by *Aphanomyces cochlioides* may not have been as severe as it was in the second planting when conditions were more favorable for its development. At the time of the second planting, temperatures were warmer and soil moisture higher due to rain and a higher water table.

It appears that soil-row treatments with captan were most successful when all or most of the seedling infection was caused by *Pythium ultimum*. In other cases where *Rhizoctonia solani, P. aphanidermatum* and especially *Aphanomyces cochlioides* played an important part; the control was less effective and in severe cases failed to provide satisfactory control.

Results of the greenhouse diagnosis (Table 2) did not indicate that *Pythium ultimum* was important in trial 7; however, this pathogen was causing the seedling infection at the time of the emergence count, as determined by diagnosis of seedlings collected from the field.

While these trials offer some encouragement for the use of row treatment, they have fallen far short of achieving the degree of control that the greenhouse trials indicate might be possible. It is possible that the method of field application may be partially responsible for the relatively poor control obtained in the field trials. Future work should investigate methods of field application, as well as search for more effective fungicides.

## Summary and Conclusions

Eight field trials were conducted to determine the effectiveness of soil-row treatment under various field conditions. It was found that:

1. The stand of sugar beet seedlings was improved by spraying fungicide in the row as the seed was planted in four out of eight trials.

2. In the two cases where damping-off was severe, soil-row treatment resulted in a commercially acceptable stand in one case, and failed to do so in the other.

3. Soil-row treatment tended to give the greatest protection when *P. ultimum* was the active pathogen.

4. More field and greenhouse trials are needed to develop a more effective treatment.

### ACKNOWLEDGMENT

The authors thank John M. Rible, Soil Science Department, University of California, Davis; Tom Ryan, Spreckels Sugar Company, and John Bryan, Spreckels Sugar Company, for assistance in conducting these trials.

## Literature Cited

(1) F. J. HILLS AND L. D. LEACH.
1952. The effect of certain soil-row treatments on damping-off of sugar beet seedlings caused by specific fungi. Am. Soc. Sugar Beet Tech. pp. 449-553.

# A Comparison of Several Methods of Testing Sugar Beet Strains and Individual Roots for Resistance to Storage Pathogens[1]

JOHN O. GASKILL[2]

Certain inoculation techniques for testing storage-rot resistance of sugar beet roots (*Beta vulgaris* L.) have been described by workers in the United States in recent years (2, 4, 5)[3], and progress in breeding for improved storage rot resistance also has been reported (3). However, the need for further information regarding inoculation techniques has been apparent in at least two respects. First, it was clear that a reliable method was needed for testing small plant populations and, second, more efficient means of screening individual mother-beet roots for resistance were much to be desired.

## Methods

In 1952 eight sugar beet strains (Table 1) representing a wide range in storage-rot resistance, as determined in earlier experiments, were grown in Latin-Square arrangement in a field near Eaton, Colorado. The crop was cared for in the usual way. At harvest, October 6-9, two representative samples of approximately 20 beets each were taken from each of the 64 field plots, topped, injured further by a uniform procedure, washed, and stored without artificial inoculation—one sample at 65° F. and the other at 45° (± 2° F.). Storage conditions were controlled as described in an earlier report (1). The duration of storage was approximately 12 and 21 weeks for the 65° and 45° temperatures, respectively. At the end of storage the percentage of rotted tissue was determined for each sample by separating and weighing the healthy and rotted portions. The percentage-rot data were summarized and analyzed with logarithmic transformation.

Representative roots for inoculation purposes also were taken from each field plot at harvest. They were trimmed as mother beets, washed, and held in crates until needed for inoculation. Storage temperatures for these roots prior to inoculation averaged about 42-45° F., relative humidity was high, and the roots remained in good condition.

The following fungus cultures were used in the inoculation trials: *Botrytis cinerea* Fr., A and A′; *Phoma betae* Frank, B and B′; and *Penicillium* sp., C. All five cultures had been isolated from sugar beet storage-rot specimens. The first two species named were emphasized in the selection of cultures since they were considered the most important pathogens in commercial sugar beet storage piles in northern Colorado.

---

[1] Report of a study made under the Research and Marketing Act of 1946 by the Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture, in cooperation with the Botany and Plant Pathology Section, Colorado Agricultural Experiment Station, and the Beet Sugar Development Foundation. This paper has been approved for publication by the Director, Colorado Agricultural Experiment Station, as Scientific Series Article No. 440.

[2] Plant Pathologist, Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture, Fort Collins, Colorado. Acknowledgment is made to J. A. Elder and L. W Lawson, Agricultural Aids, for assistance in conducting the experimental work.

[3] Numbers in parentheses refer to literature cited.

Table 1.—Description of Sugar Beet Varieties or Strains.

| Temporary Strain No. | Fort Collins Seed No. | Description |
|---|---|---|
| 1 | 471004-0 | U. S. 226 (synthetic commercial variety; leaf-spot resistant). |
| 2 | 511803-00 | Storage-rot-resistant selection from U. S. 226. |
| 3 | Acc. 1181 | G. W. 304-50A (commercial variety; leaf-spot resistant.) |
| 4 | Acc. 5072 | U. S. 22/3 (commercial variety; curly-top resistant). |
| 5 | Acc. 1139 | S. L. 1-300 (Increase of R and G Old Type). |
| 6 | 471003-0 | High-yielding inbred. |
| 7 | 461020-0 | High-yielding inbred. |
| 8 | Acc. 1216 | High-yielding inbred. |

Inoculation techniques studied were as follows:

1. Agar inoculum placed on freshly exposed surface of transverse slice of tap root as described in an earlier report (4); slice approximately 1 inch thick.

2. Agar inoculum applied to a small area exposed by removal of the epidermis from section of tap root.

3. Spore-suspension inoculum, prepared with 1:1000 Dreft solution, placed on transverse slice as in method 1.

4. Sterile, wooden toothpick dipped in spore suspension (1:1000 Dreft solution) and driven approximately 1 inch into the tap root.

Any one inoculation trial—i.e., one fungus culture and one technique at a given date—involved two sugar beet roots from each of the 64 field plots, with duplicate inoculations for each root. Two sets of inoculation trials were conducted—one begun December 15-16, 1952 and the other March 26-27, 1953. Methods 1 and 2 were used in the former, and 1, 3, and 4 in the latter. Following inoculation, specimens were held at 45° F. (± 1°)

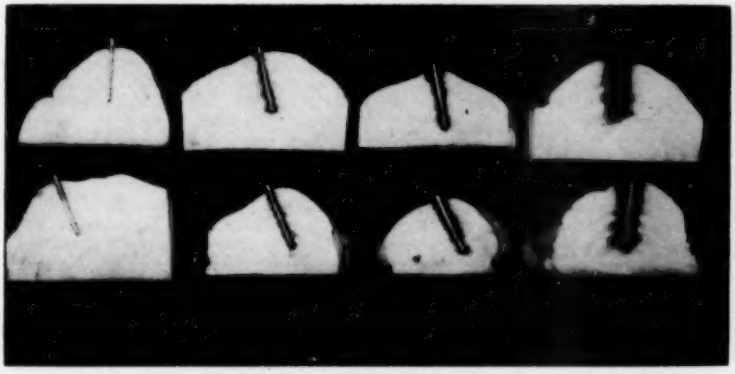

**Figure 1. Cross-sectional view of sugar beet roots showing varying reaction to *B. cinerea* toothpick inoculation. The pair of slices at the left represents two control roots. The other three pairs, from left to right, represent three respective roots which had been inoculated in duplicate and ranged from resistant to very susceptible. All roots were held for 25 days at 45° F. after the toothpicks were inserted.**

for 25 to 42 days with relative humidity between 97 and 100 percent, approximately. Depth of rotted tissue was measured for each inoculated spot for methods 1, 2, and 3. For method 4 the average width of the rotted section surrounding the toothpick was recorded, with the root cut transversely as illustrated in Figure 1.

## Results

The percentage rot data obtained from the samples which were not inoculated artificially failed to show significant interaction of beet strains x temperatures, and the results were combined into the single set of averages shown at the left in Tables 2 and 3. As indicated by the F-test, highly significant differences occurred between strains. Laboratory platings made from rotting specimens taken from comparable samples near the end of storage indicated that *B. cinerea* and *P. betae* were the principal pathogens affecting the uninoculated roots. No attempt was made to appraise the relative importance of the two. The latter occurred with greater frequency in the plates, but a tendency toward more severe rotting action was noticed for the former, and both were considered important.

**Table 2.—Storage Rot in Uninoculated Samples of Eight Sugar Beet Strains and in Comparable Root Tissue Specimens Inoculated by Two Methods, December 15-16, 1952.**

| Sugar Beet Strains | Rot in[1] Uninoculated Samples (Geom. Mean) | Fuhgus Cultures, Time, and Average Depth of Rotted Tissue[2] Inoculation Method 1 A (Botrytis) 32 Days | B (Phoma) 32 Days | C (Penicillium) 34 Days | Inoculation Method 2 A (Botrytis) 42 Days | B (Phoma) 42 Days | C (Penicillium) 42 Days |
|---|---|---|---|---|---|---|---|
| | Percent | Mm. | Mm. | Mm. | Mm. | Mm. | Mm. |
| 1 | 2.89 | 7.5 | 4.8 | 2.6 | 0.7 | 0.7 | 0.05 |
| 2 | 1.73 | 6.1 | 5.7 | 2.6 | 0.3 | 2.4 | 0.25 |
| 3 | 2.07 | 6.6 | 3.9 | 2.5 | 0.8 | 1.2 | 0.23 |
| 4 | 4.42 | 7.0 | 4.4 | 3.8 | 1.7 | 1.8 | 0.16 |
| 5 | 3.08 | 6.6 | 5.0 | 3.6 | 2.3 | 1.7 | 0.06 |
| 6 | 7.03 | 10.3 | 3.8 | 2.5 | 2.7 | 0.7 | 0.08 |
| 7 | 7.03 | 10.2 | 4.5 | 2.9 | 1.7 | 0.5 | 0.08 |
| 8 | 6.46 | 14.5 | 8.0 | 3.4 | 1.2 | 2.9 | 0.25 |
| General mean | | 8.59 | 5.01 | 2.97 | 1.40 | 1.52 | 0.14 |
| F | 4.55[6] | 6.73[6] | 3.55[6] | 0.68 | 1.10 | 1.08 | [3] |
| C.V. | | 36.7 | 40.5 | 61.3 | 157.4 | 144.4 | [3] |
| L.S.D. (5 percent point) | | 3.2 | 2.0 | 1.8 | 2.2 | 2.2 | [3] |
| r[4] | | 0.81[5] | 0.13 | 0.16 | 0.62 | —0.19 | —0.25 |

[1] 65° and 45° F. combined; total of approximately 320 roots per strain.
[2] Each strain average based on 16 roots (32 inoculations); temperature 45° F.
[3] Variance analysis was omitted due to the relatively high frequency of zero determinations.
[4] Correlation of the indicated column with rot percentages for uninoculated samples.
[5] = Odds at least 19:1.
[6] = Odds at least 99:1.

Summarized results for the December and March inoculation trials are presented in Tables 2 and 3, respectively. Considering, first, the significance of differences between beet strains (as measured by F), the coefficient of variability (C.V.), and the relative degree of pathogenic action, certain observations seem to deserve special mention:

1. Method 2 appeared to be unsatisfactory in each of the three trials in which it was used. In the case of *Penicillium* sp., although variance analysis was not made, erratic results and frequent occurrence of zero determinations were sufficient to reject the method insofar as that particular culture was concerned. The method 2 trials involving *B. cinerea* and *P. betae* failed to show significant differences between strains, and the C. V.-values were extremely high.

2. In the only other trial involving *Penicillum* sp. (method 1, culture C), the results also were unsatisfactory as evidenced by low F and high C. V.

3. In every trial in which *B. cinerea* or *P. betae* was used, with the exception of method 2, the F value showed that significant differences occurred between strains. However, because of higher C. V. values, method 3 appeared to be less desirable than 1 and 4.

**Table 3.—Storage Rot in Uninoculated Samples of Eight Sugar Beet Strains and in Comparable Roots and Root-Tissue Specimens Inoculated by Means of Three Methods, March 26-27, 1953.**

| | | Fungus Cultures, Time, and Average Rot Measurements[2] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Inoculation Method 1 | | | | Inoc. Method 3 | | Inoc. Method 4 | |
| | | Botrytis | | Phoma | | Botrytis | Phoma | Botrytis | Phoma |
| Sugar Beet Strains | Rot in[1] Uninoculated Samples (Geom. Mean) | Cult. A 25 Days | Cult. A′ 25 Days | Cult. B 26 Days | Cult. B′ 25 Days | Cult. A′ 25 Days | Cult. B′ 25 Days | Cult. A′ 26-27 Days | Cult. B′ 26-27 Days |
| | Percent | Mm. | Mm. | Mm. | Mm. | Mm. | Mm. | Mm. | Mm. |
| 1 | 2.89 | 10.3 | 12.0 | 8.9 | 6.8 | 9.0 | 1.3 | 10.9 | 3.5 |
| 2 | 1.73 | 8.1 | 8.5 | 7.5 | 5.7 | 4.3 | 0.8 | 7.6 | 3.0 |
| 3 | 2.07 | 9.2 | 9.3 | 6.7 | 5.5 | 6.9 | 0.6 | 9.3 | 3.6 |
| 4 | 4.42 | 9.1 | 10.5 | 9.4 | 7.6 | 7.4 | 0.7 | 7.8 | 2.7 |
| 5 | 3.08 | 9.2 | 10.9 | 8.7 | 6.3 | 6.2 | 0.7 | 9.2 | 4.4 |
| 6 | 7.03 | 13.5 | 14.1 | 8.0 | 6.7 | 8.8 | 0.7 | 10.5 | 3.7 |
| 7 | 7.03 | 10.3 | 11.7 | 8.2 | 6.9 | 7.8 | 1.5 | 10.6 | 3.1 |
| 8 | 6.46 | 14.1 | 14.6 | 11.7 | 9.8 | 16.8 | 2.5 | 12.3 | 4.2 |
| General mean | | 10.46 | 11.45 | 8.62 | 6.91 | 8.38 | 1.09 | 9.77 | 3.51 |
| F | 4.55[3] | 4.48[3] | 2.98[5] | 3.42[3] | 3.59[6] | 6.63[3] | 2.72[5] | 2.95[5] | 3.31[6] |
| C.V. | | 27.8 | 30.9 | 26.3 | 28.9 | 48.8 | 103.6 | 27.1 | 25.4 |
| L.S.D.[3] | | 2.9 | 3.6 | 2.3 | 2.0 | 4.1 | 1.1 | 2.7 | 0.9 |
| r[4] | | 0.77[5] | 0.81[5] | 0.45 | 0.61 | 0.57 | 0.50 | 0.61 | 0.09 |

[1] 65° and 45° F. combined; total of approximately 320 roots per strain.
[2] Each strain average based on 16 roots (32 inoculations); temperature 45° F. Measurements for method 4 represent average width of rotted section surrounding the toothpick; all other measurements represent depth of rotted tissue.
[3] Five percent point.
[4] Correlation of the indicated column with rot percentages for uninoculated samples.
[5] = Odds at least 19:1.
[6] = Odds at least 99:1.

The following highlights observed in comparing the sugar beet strain averages obtained from inoculation trials with the strain averages obtained from uninoculated samples are of interest:

1. In general the results from trials with *B. cinerea* agreed much more closely with the uninoculated samples than did the data from *P. betae* inoculation.

2. In each of the three trials in which *B. cinerea* was used with inoculation method 1, the r value was significant (0.81, 0.77, and 0.81, respectively).

3. The strain averages obtained for method 4, with *B. cinerea,* agreed fairly well with those for the uninoculated samples, the r value (0.61) approaching significance.

4. The results for method 4, with *B. cinerea,* agreed quite closely with those obtained for the comparable trial under method 1 (Table 3, culture A'). The r-value in this case, 0.85 (not shown in table), was highly significant.

The behavior of strains 1 and 2 in the inoculation trials is of special interest. Strain 1 is U. S. 226, a wide-base synthetic variety. Strain 2 was developed from U. S. 226 by two generations of selection for storage-rot resistance. In each of the six inoculation trials involving *B. cinerea,* strain 2 was below the parental variety in average rot measurement. The difference was significant in two trials, approximately so in a third, and general averages based on all six trials showed strain 2 to be 31 percent below No. 1. These data strongly indicate that strain 2 is superior to the parental variety in resistance to *B. cinerea.* The results are in agreement with those from uninoculated samples, though the difference between the two strains in the latter comparison was not significant. In contrast with the findings for *Botrytis,* the difference between strains 1 and 2 in reaction to *P. betae* was negligible. In the 6 trials in which the latter species was used, none of the mean differences between those strains was significant, and the two general strain averages were practically identical. From these data it seems clear that improvement in resistance to *B. cinerea* by selection is feasible, in the U. S. 226 variety, and that such improvement does not necessarily constitute better resistance to *P. betae.*.. This apparent independence of resistance to the two fungi is in keeping with the contrasting correlations discussed above.

Evidence indicating that resistance decreases during storage may be seen in Tables 2 and 3, cultures A and B, inoculation method 1. The rate of rotting as measured by the general mean was 0.27 mm. per day for *Botrytis*-culture A when inoculations were performed in mid-December, 1952. The corresponding mean for the series of inoculations performed late in March, 1953, was 0.42, an increase of 56 percent. Similar results were obtained for *Phoma*-culture B, the average for March inoculations (0.33 mm. per day) being more than double the rate for the December trial.

## Summary

An experiment was conducted primarily for the purpose of studying inoculation methods for testing sugar beet strains and individual roots for resistance to storage pathogens. Roots of eight strains grown in replicated field plots, were injured uniformly at harvest and stored without artificial inoculation under controlled conditions—a total of approximately 320 roots per strain. At the end of storage the percentage of rotted tissue was determined for each sample.

Comparable roots from the same field plots were inoculated in four different ways using a total of five fungus cultures representing three species.

Fourteen inoculation trials were conducted, each trial at a given date involving a single fungus culture, one method of inoculation, and a total of 16 roots (32 inoculations) for each sugar beet strain. The amount of rot was determined by measurement several weeks after inoculation.

Highly significant differences between beet strains, in percentage of rotted tissue, occurred in the set of uninoculated samples as shown by an F value for strains in excess of the 1 percent point.

Appraisal of precision by means of the F test indicated that, for *B. cinerea* and *P. betae* inoculations with methods 1 and 4, samples of 16 roots per strain were nearly as effective as were samples of approximately 320 uninoculated roots as a means of showing the occurrence of significant differences between strains.

The average rates of rotting for the 8 respective sugar beet strains in each of the three *Botrytis* inoculation trials in which method 1 (interior agar technique) was used agreed quite well with the percentage-rot averages obtained from uninoculated samples (significant r values 0.81, 0.77 and 0.81, respectively). The results obtained for *Botrytis* with method 4 (toothpick-spore-suspension procedure) agreed fairly well with the uninoculated samples (r 0.61) and closely paralleled the comparable results for method 1 (r 0.85, highly significant). The data obtained from *Phoma* inoculations, in general, did not agree closely with the uninoculated samples.

Strain 2 which had been selected for storage-rot resistance from U. S. 226 (strain 1), was substantially superior to the parental variety in resistance to *B. cinerea,* but there was essentially no difference between the two strains in reaction to *P. betae.* These results indicated (a) that improvement in storage-rot resistance, by selection, is feasible insofar as *B. cinerea* is concerned; and (b) that improved resistance to that pathogen does not necessarily constitute better resistance to *P. betae.*

Comparable inoculations performed in December, 1952, and in the following March, using *B. cinerea* and *P. betae,* showed considerable loss in resistance to each fungus during the intervening period, in spite of the fact that the roots were held under conditions generally considered quite satisfactory for mother beet storage.

### Literature Cited

(1) GASKILL, JOHN O.
1950. Effects of wilting, drought, and temperature upon rotting of sugar beets during storage. Proc. Amer. Soc. Sug. Beet Tech. 6th General Meeting: 653-659.

(2) GASKILL, JOHN O.
1950. Possibilities for improving storage-rot resistance of sugar beets through breeding. Proc. Amer. Soc. Sug. Beet Tech. 6th General Meeting: 664-669.

(3) GASKILL, JOHN O.
1952. Progress report on breeding for storage-rot resistance in sugar beets. Proc. Amer. Soc. Sug. Beet Tech. 7th General Meeting: 396-399.

(4) GASKILL, JOHN O.
1952. A study of two methods of testing individual sugar-beet roots for resistance to storage pathogens. Proc. Amer. Soc. Sug. Beet Tech. 7th General Meeting: 575-580.

(5) NELSON R. T., and OLDEMEYER, R. K.
1952. Preliminary studies applicable to selection for low respiration and resistance to storage rots of sugar beets. Proc. Amer. Soc. Sug. Beet Tech. 7th General Meeting: 400-406.

# Identification of Some Materials in Root Exudates of Nematode (Heterodera Schachtii, Schmidt) Host Plants

R. R. Wood and R. F. Serro[1]

## Introduction

The problem of control of the sugar beet nematode (*H. schachtii*, Schmidt) appears to be almost universal wherever the crop is grown. The trouble was early noted by Europeans on land having a history of many successive beet crops. They termed the land "beet sick." According to Stewart (1)[2], et al, in 1881-82 Julius Kuhn and others fixed the responsibility for the damage on the eelworm of the sugar beet nematode.

Baunacke (2), in 1922 recognized the presence of some substance having a stimulating effect on the larvae in the drainage water from sugar beet plantings; also, that an infested plant ceases to send out chemical stimulii which would attract new larvae in the area. He does not state how he was sure the stimulii were of a chemical nature, but in the final paragraph of the article it is suggested that isolation of the chemical in the root secretion would, no doubt, facilitate activation of the larvae in the soil. Apparently attempts to isolate individual fractions in the root exudate had already proven unsuccessful by methods then available.

The principal control thus far employed has been crop rotation, using non-host crops. Baunacke (2) mentioned the possibility of use of ammonia as a soil fumigant and also the planting of a trap crop.

Thorne and Jensen (3), 1946, reported successful use of two chemicals, "D-D," and "Dowfume W15" as soil fumigants in field scale experiments in 1944 and 1945. However, for extensive infestation and for all types of soil, these materials have not found wide acceptance with growers.

## Materials and Methods

Plants of each of the following species were taken from the soil, care being observed in washing off soil particles adhering to the roots to leave as great a mass of the roots as possible. These plants were then placed each in a separate 500-cc. Erlenmeyer flask filled with distilled water and left for ten days.

1. Sugar beet (*Beta vulgaris L.*)
2. *Beta patellaris*
3. Alfalfa (*Medicago Sativa*)
4. Sweet clover (*Melilotus Alba*)
5. Cheat grass (*Bromus Tectorum*)

Five to seven plants of each species were used, and the root diffusate solutions resulting were composited for each species to form one sample for analysis.

---

[1] Agronomist, Agricultural Experiment Station, and Denver Research Laboratory, the Great Western Sugar Company, respectively.

[2] Numbers in parentheses refer to literature cited.

The combined root diffusates were evaporated under reduced pressure to about one thirty-fifth of their original volume (from 1,750 ml. to 50 ml. in most cases). The concentrated solutions were then qualitatively tested for ketose containing carbohydrates and reducing sugars by the standard α-naphthol ring test, and for hydrolyzable carbohydrates containing reducing sugars by a modified Dische test (4).

Chromatographic analyses were then run on the concentrates for amino acids common sugars, and polyol-type carbohydrates.

In each case paper chromatography was used, with 160 micro-liters of concentrated diffusate per spot applied in 30 increments.

The amino acid chromatograms were run upflow under glass in the standard phenol solvent, dried, and developed with ninhydrin spray.

Common sugars were determined by the technique of Albon and Gross (5) using the propanol solvent and α-naphthol spray.

The polyols were determined by the use of chromatograms run in collidine solvent, dried and developed with silver nitrate spray (4).

## Analytical Results

Table 1 gives information on the results of qualitative tests run on the concentrated root diffusates.

**Table 1.—Qualitative Results of Color Tests and Paper Chromatography of Root Diffusates.**

| Plant | % Solids in Concentrate | a-Naphthol Test | Dische Test | Amino Acids found | Carbohydrates found |
|---|---|---|---|---|---|
| Sugar beet | 0.10 | Negative | Trace | Glutamic acid | Galactinol[1] and Inositol |
| *Beta patellaris* | 0.12 | Negative | Trace | Glutamic acid | Galactinol[1] and Inositol |
| Alfalfa | 0.24 | Negative | Positive | None | Galactinol[1] and Inositol |
| Sweet clover | 0.27 | Negative | Positive | None | Galactinol[1] and Inositol |
| Cheat grass | 0.12 | Negative | Positive | None | Galactinol[1] and Inositol |

[1] Galactinol is a new carbohydrate recently isolated by Brown and Serro (4) from beets and beet products. It is an α-galactoside of inositol.

The results of the qualitative tests indicate that no standard hexoses, sucrose or raffinose were present, but that there was a carbohydrate present with a reducing sugar available after the strong acid hydrolysis of the Dische test.

The identity of the polyols found in the silver chromatograms was tentatively identified by chromatographic comparison with known compounds.

The concentrations of the two carbohydrates found were estimated by comparison with standard quantities of known inositol and galactinol. These estimates of concentrations in the original solutions are listed in Table 2.

While it is recognized that chromatographic evidence does not constitute proof of identity of the compounds listed, the tests do lead to the conclusion that the materials found are at least closely related to the postulated compounds, and more probably are the same.

**Table 2.—Estimated Concentrations of Organic Substances Found in Root Diffusate Solutions.**

| Plant | i-Inositol | Galactinol | Glutamic acid |
|---|---|---|---|
| | ppm. | ppm. | ppm. |
| Sugar beet | 50 | 5 | Less than 2 |
| *Beta patellaris* | 26 | 2.6 | Trace |
| Alfalfa | 35 | 10 | None |
| Sweet clover | 26 | 5 | None |
| Cheat grass | 35 | 10 | None |

It is interesting to note that the other plants tested, alfala, sweet clover, and cheat grass, also appear to secrete the two substances, i-Inositol and Galactinol, while glutamic acid was absent. This suggests that reduction in nematode population numbers, as result of crop rotations, could be due in part to secretion of stimulatory substances by the roots of non-host plants.

## Biological Materials and Methods

Distilled water solutions of the pure materials of each of the 3 substances described above were used at various concentrations in an attempt to stimulate the hatching of the eelworms from the encysted eggs. The following concentrations were employed:

1. i-Inositol at 100, 50, 25 and 12.5 parts per million.
2. Galactinol at 10, 5, 2.5 and 1.25 ppm.
3. Glutamic acid at 10, 5, 2.5 and 1.25 ppm.

In addition, diffusate solutions from sugar beet and *Beta patellaris*, with appropriate distilled water controls, were tested for stimulatory effect on the dormant cysts.

Cysts were collected from air-dry infested soil, using essentially the flotation technique described by Goodey (6).

Cells of about 7 mm. in diameter were cut in paraffin layer about 3 to 4 mm. deep in a petri dish by the use of a cork borer. Within each cell was placed 3 cysts, care being taken to use fairly plump appearing cysts without any broken walls. A few drops of the material in solution to be tested was then pipetted into the cell. Four cells of each concentration of each chemical were used. The first attempts were made with the cells in the top half of the petri dish, with the solution and cysts somewhat as a suspended drop, the reason being to enhance the aeration of the solution containing the cysts. Later in the trial, the dishes were reversed to make easier observation with the binoculars. In all, two separate hatching experiments were conducted, and in the second trial the cells were always in the lower one-half of the petri dish. Each experiment comprised about one month's time.

[3] Private communication, Thorne, Gerald, Senior Nematologist, U. S. Department of Agriculture, Salt Lake City, Utah.
[4] Private communication, Steiner, G., U. S. Department of Agriculture, Beltsville, Maryland.

## Experimental Results

In Table 3 are found the summarized results of the two trials.

Thorne[3] points out that under conditions of his experiments, considerable hatching may be induced by unchlorinated stream water. It was noted in the experiments reported here that only one case showed any hatching

**Table 3.—Average Number of Eelworms per Cyst Hatched in Solutions of Three Chemicals at Various Concentrations.**

| Chemical Solution | Concentration ppm. | Eelworms per Cyst Average of 8 cells |
|---|---|---|
| i-Inositol | 100 | 1.6 |
| | 50 | 0.04 |
| | 25 | 0.37 |
| | 12.5 | 0.09 |
| Galactinol | 10 | 1.6 |
| | 5 | 1.5 |
| | 2.5 | 3.3 |
| | 1.25 | 0.21 |
| Glutamic acid | 10 | 1.0 |
| | 5 | 0.04 |
| | 2.5 | .00 |
| | 1.25 | 2.1 |
| *Beta patellaris* diffusate | | 0.12 |
| Sugar beet diffusate | | 0.42 |
| Distilled water | | 0.03 |

in the cells containing distilled water, and in that case there could have been some admixture of chemical from an adjoining cell. Many investigators[3,4] mention the difficulty of identifying cysts containing viable eggs. Some have overcome such a problem in their hatching experiments by the use of large numbers (50 or more) of cysts.

## Summary

Three chemicals, i-inositol, galactinol and glutamic acid, appear from these experiments to constitute a major portion of the exudate from roots of nematode host and some non-host plants. The approximate concentration in the water solution in which the plants grew is given, but further work would be needed to determine whether the same concentration would be built up by secretion into the soil mass. The results of the hatching experiment reported here are no doubt limited by the numbers of cysts used, and should be considered only as suggestive of a line of attack for further investigation.

## Literature Cited

(1) STEWART, GEORGE and BATEMAN, A. H.
1926. Field studies of sugar beet nematode. Bulletin No. 195, Utah Agricultural Experiment Station, May, 1926.

(2) BAUNACKE, W.
1922. Investigations on the biology and control of the beet nematode, *Heterodera Schachtii*, Schmidt. Contributions of the Biological Institute for Agriculture and Forestry, Berlin. Translated by Ernst Artschwager, February, 1953.

(3) THORNE, GERALD and JENSEN, VERNAL.
1946. A preliminary report on the control of sugar beet nematode with two chemicals, D-D and Dowfume W15. Proc. Amer. Soc. Sug. Beet Tech. pp. 322-326.

(4) BROWN, ROBERT J. and SERRO, ROBERT F.
1953. Isolation and identification of O-&-D-Galactopryanosyl-myo-inositol and of myo-inositol from juice of the sugar beet (*Beta vulgaris*). Jour. Amer. Chem. Soc. 75:1040 (1953).

(5) ALBON, N. and GROSS, D.
1952. The Analyst 77:410 (1952).

(6) GOODEY, T.
1951. Laboratory methods for work with plant and soil nematodes. Tech. Bulletin No. 2, Ministry of Agriculture and Fisheries, Rothamsted Experimental Station (England).

# Endrin—A New Insecticide for Sugar Beet Webworm Control[1]

R. E. Hamman and R. T. Nelson[2]

With the advent of the chlorinated hydrocarbon and organic phosphate insecticides following World War II, insect control studies have taken a prominent place in the agricultural research programs of state and federal experiment stations as well as private industry. Any discussion at this meeting on bettering the quality as well as the quantity of sugar beets would not be complete without mentioning some of the latest results which have been obtained in man's never ending struggle with insects for possession of our food supply, in this instance sugar beets.

One of the more important pests attacking sugar beets, particularly in the Rocky Mountain and Great Plains states, is the sugar beet webworm (*Loxostege sticticalis* (L)). Outbreaks of this pest are sporadic, varying with generations within a season as well as with locality and season. In spite of this irregularity of infestation more money is probably spent on sugar beet webworm control than on any other insect pest attacking sugar beets.

Paris green was formerly the standard insecticide for webworm control, followed for a short period by pyrethrum. In 1951, Douglass and Romney (1)[3] reported on the comparative toxicity of several new insecticides to the sugar beet webworm. Included in this study was a material known as Compound 269 which was later given the common name Endrin. This material has shown considerable promise against a variety of lepidopterous pests including tobacco hornworms, tobacco budworm, cotton bollworm, cotton leafworm, cabbageworms, corn earworm, armyworms and cutworms. Because of the excellent control of sugar beet webworm with Endrin shown by Douglass and Romney plans were made to evaluate Endrin on a field scale basis in 1952. Lack of sufficient webworm infestation in 1952 delayed field evaluation until 1953.

## Methods and Results

At the first appearance of sugar beet webworm larvae near Longmont, Colorado, in June, 1953, small plot tests were initiated which included Endrin as well as other chemicals presently being used for webworm control. It was immediately apparent that a dosage rate of 0.2 pound Endrin per acre gave rapid and outstanding control of first and second instar webworm. Subsequent treatment of large fields, both by air and by ground equipment, substantiated this finding. In order to give Endrin a thorough testing, arrangements were made to obtain sufficient supplies of Endrin to treat a large percentage of the sugar beet acreage under contract to the Longmont plant of the Great Western Sugar Company. Since the entire infestation period of this generation of webworm would last no longer than three weeks,

---

[1] Approval of label was obtained February 4, 1954, for use of Endrin on sugar beets.

[2] Entomologist, Shell Chemical Corporation, Agricultural Chemicals Division, Denver, Colorado, and Plant Physiologist, Great Western Sugar Company, Longmont, Colorado, respectively.

[3] Numbers in parentheses refer to literature cited.

a dosage rate of 0.3 pound Endrin per acre was decided upon as an average rate in view of the premise that webworms are more difficult to kill as they increase in size.

Simultaneously with the experimental program at Longmont similar programs of smaller scope were begun at the Scottsbluff, Nebraska, and Billings, Montana, plants of Great Western Sugar Company as well as at the Worland, Wyoming, plant of Holly Sugar Company. Results of these tests are given in Table 1.

**Table 1.—Sugar Beet Webworm Control Obtained with Endrin in Terms of Total Farms and Acreage Involved.**

| Lbs. Endrin/Acre | Total Farms | Total Acreage | Degree of Control | | |
|---|---|---|---|---|---|
| | | | Fair | Good | Excellent |
| 0.3 | 67 | 1,666 | 1/20[1] | 6/120[1] | 60/1526 |
| 0.4 | 24 | 394 | 0/0 | 2/30 | 22/364 |
| Total | 91 | 2,060 | 1/20 | 8/150 | 82/1890 |

[1] 1/20 = 1 farm/20 acres; 6/120 = 6 farms/120 acres

As indicated in the tabulation of results, Table 1, Endrin was used on 91 farms totalling 2,060 acres in this field scale evaluation for sugar beet webworm control. A dosage rate of 0.3 pound actual Endrin per acre was used on 67 farms totalling 1,666 acres. A dosage rate of 0.4 pound actual Endrin per acre was used on 24 farms totalling 394 acres. Control was rated as fair, good or excellent. Excellent results were obtained on 82 farms totalling 1,890 acres; good results were found on 8 farms totalling 150 acres; and fair results were obtained on 1 farm totalling 20 acres.

Compiled notes of observations by the writers, agricultural managers and fieldmen of the various cooperating agencies indicated the following:

1. Webworm kill was quick and complete on a high percentage of the population. This was the case whether the worms were small or large.

2. The control and kill of worms were commonly obtained within a 12-hour period after treatment.

3. In cases where kill was not obtained within the 12-hour period, a residual toxicity of Endrin was evidenced by better control during subsequent observations.

4. Worms were noted as continuing to die over as long a period as 4 to 5 days after treatment. This was particularly noticeable in one field which was partly treated when the oldest worms were no more than in the second instar stage of development. Numerous eggs were still unhatched. Control of webworm on the treated area was highly effective, and the contrast in webworm population and insect-riddled beet leaves of the treated versus untreated area became increasingly apparent as the webworm season progressed.

5. Consistency of results with Endrin over a wide range of conditions was apparent and contrasted with varying results encountered in use of other insecticides.

6. Endrin was easily applied as an emulsion in water with standard spraying equipment. There was no injury to sugar beet foliage from this emulsion.

## Toxicology

No cases of toxic effects to operators of ground or air equipment were reported. Standard precautions observed with any of the chlorinated hydrocarbons should be observed when using Endrin. These should include:

1. Wash thoroughly with soap and water after handling and before eating or smoking.
2. Wear clean clothing.
3. In case of accidental spillage on person or clothing, immediately remove clothing and flush skin or eyes with plenty of water; for eyes, get medical attention.

## Residues

Sugar beet pulp taken from beets treated with Endrin at dosage rates of 0.3-0.6 pound actual Endrin per acre both at 20-and 90-day intervals before harvest analyzed less than 0.1 part per million, this figure being the sensitivity of the method.

**Table 2.—Residue Analysis, Sugar Beet Pulp and Tops Treated with Endrin.**

| Type of Material | Lbs. Endrin /Acre | No. of Applications | Interval Treatment to Harvest | Toxicant Found, ppm |
|---|---|---|---|---|
| Sugar beet pulp | 0.3 | 1 | 90 | <0.1[1] |
| Sugar beet pulp | 0.4 | 1 | 90 | <0.1 |
| Sugar beet pulp | 0.3 | 1 | 20 | <0.1 |
| Sugar beet pulp | 0.6 | 1 | 20 | <0.1 |
| Sugar beet tops | 0.3 | 1 | 90 | <0.1 |
| Sugar beet tops | 0.4 | 1 | 90 | <0.1 |
| Sugar beet tops | 0.3 | 1 | 20 | 0.64 |
| Sugar beet tops | 0.6 | 1 | 20 | 0.84 |

[1] Values are based on several individual analyses made on composite samples.

Sugar beet tops treated 90 days ahead of harvest at dosage rates of 0.3-0.4 pound actual Endrin analyzed less than 0.1 part per million. Sugar beet tops treated 20 days ahead of harvest at a dosage rate of 0.3 pound actual Endrin per acre analyzed 0.64 part per million while a dosage rate of 0.6 pound actual Endrin per acre analyzed 0.84 part per million. No rainfall occurred in the test area during the 20-day period from application to harvest. There is no known translocation of Endrin within plant tissues, and the results of Table 2 add further confirmation that Endrin is not translocated.

## Status of Recommendations

The above data have been submitted to the Labelling Division, Production and Marketing Administration, Washington, D. C., in support of a label application for the use of Endrin against the sugar beet webworm. Approval is pending.

## Literature Cited

(1) DOUGLAS, J. R. and ROMNEY, VAN E.
1952. Comparative toxicity of some new insecticides to the sugar beet webworm in Colorado, 1951. Proc. Amer. Soc. Sugar Beet Tech. pp. 503-506.

# AGRICULTURAL ENGINEERING

# Minimum Seed Bed Preparation

M. G. FRAKES[1]

Heavy sugar beet soils, in the eastern area, when packed down by excessive tillage operations or heavy rains, result in a condition of very poorly aerated soil. This induces excessive attacks by blackroot organisms and causes nitrogen deficiencies as well as poor growth generally. It has been shown conclusively that sugar beets are very sensitive to excessive soil packing and conditions of poor aeration (1), (2).[2]

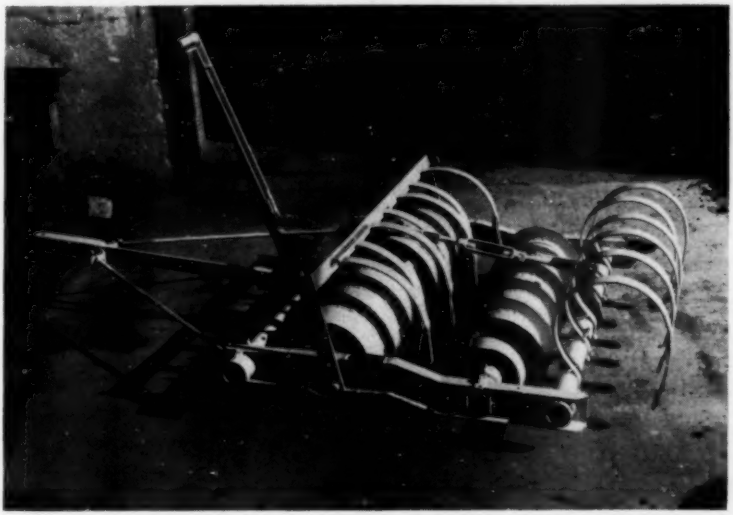

**Figure 1.—A "Once Over Tiller" with a double bank of spring teeth which are independently adjustable for depth. It is attached to a two- or three-bottom plow and prepares the seed bed at the same time the soil is plowed.**

It would appear that the idea of double discing, two or three harrowings, leveling and a final harrowing for "weed control" to produce a "fine, firmly packed" seed bed is not the best procedure for obtaining a seed bed under Michigan conditions. Excessive soil packing by tractor wheels and heavy machinery, plus subsequent rainfall, packs heavy soils to a point where yields of sugar beets, and other crops as well, are materially reduced. This is especially true of soils which have been heavily cropped with cash crops and in which the soil organic matter is low. Also, yields are particularly sensitive to soil compaction in those areas where drainage is a problem. Consequently, sugar beet growers are rapidly adopting a system of minimum seed bed preparation.

---

[1] Agricultural Research Director, Michigan Sugar Company, Saginaw, Michigan.
[2] Numbers in parentheses refer to literature cited.

### What Is Minimum Seed Bed Preparation?

"Minimum Seed Bed Preparation" is a system whereby a grower plows his soil with a leveling or mulching tool attached to the plow. The soil is worked and packed somewhat in the same operation as plowing. Several tools are commercially available for attaching to plows for this purpose although sections of spike-tooth harrows, spring-tooth harrows or even a heavy plank or post have been attached to level off the newly turned furrows. One of the commercial-type tools used for this purpose is shown in Figure 1. This particular tool, called "The Once Over Tiller" breaks up clods, packs the soil to a limited extent and the adjustable spring teeth permit a slight mulching of the soil to aid in preventing crusting by subsequent rains.

Immediately after plowing with one of these tools attached to the plow, the field is planted. It is more advantageous if the field is planted the afternoon of the day on which plowing was accomplished. Many growers have two tractors in the field, one plowing and the other planting. The important point is that no tractor goes over the newly plowed ground until the one which pulls the drill.

### Precautions

As with any new practice which is adopted by growers, it is necessary that certain precautions be taken in some phases of the process. It is necessary that the tractor be centered in the rows in accordance with the drill so that it will be easier to cultivate. If the tractor wheels are not centered directly between the rows when planting, subsequent operations with the cultivator may cause some difficulties. In the eastern area, a four-row drill is used in planting 28-inch rows. The cultivating is accomplished with four-row cultivators. Some difficulty may be encountered if this procedure is used with a six-row drill, using narrower rows which are cultivated three rows at a time.

When planting in loose soil, such as is accomplished with this system, the surface is not altogether smooth. Consequently, some growers have encountered difficulty in adjusting gauge wheels for mechanical thinners. This problem has been overcome by the use of gauge wheels directly on the sugar beet row itself.

The use of minimum seed bed preparation as described herein is not a cure-all for plowing soil too wet. The soil should be plowed with the optimum moisture content as with any other system of seed bed preparation. It is important that the planting operation occur very soon after plowing.

### Results

Many growers have obtained excellent results with the use of minimum seed bed preparation other than the obvious saving which is accomplished both in time and expense in preparing a seed bed. Some of the results obtained have been:

1. Quicker and better emergence.
2. There are fewer weeds up to cultivation time. Sugar beets get

a head start over weeds and they can be easily controlled. It has also been noted that there are considerably fewer weeds in crops, such as corn or beans, when this method of tillage is used.

3. It has been found there is more moisture available for summer growth. The spring rains which occur in Michigan very often run off of soils which have been packed excessively. With minimum seed bed preparation, a three- to four-inch rain will sink into the soil and will be available for later growth of the plants.

4. It has been noted that there was less crusting in those fields which have been prepared with minimum seed bed preparation. The soil is more friable throughout the root zone all during the growing period.

5. Higher yields have been obtained in a majority of the cases. Many times a grower has doubled his yield. However, such drastic increases occur on soils relatively low in organic matter or where drainage is at a minimum. These cases refer to the six- to seven-ton yield farm, which, following this method of tillage, has produced 12 to 14 tons per acre. We have found that where this practice is followed on the 12- to 14-ton per acre sugar beet farm the yield increases but two to three tons.

6. In those years in which there is an excessive amount of rainfall in the spring, as often occurs under Michigan conditions, it is sometimes possible to get a crop planted using minimum tillage when time is at a premium. We have had many cases in which the use of minimum seed bed preparation meant the difference between getting a crop and no crop at all.

Perhaps equally as important as minimum seed bed preparation is the practice which should be followed, either with or without this system, and that is what we term "Deep Tillage."

### What Is Deep Tillage?

"Deep Tillage" is the use of Graham-Hoeme plows, field cultivators with part of the teeth removed, or any other deep tillage implement used on a field to break up the hard compact layer often called the "Plowsole." This should be done in August or September. The primary purpose of deep tillage is two fold:

1. To control perennial weeds, primarily quack grass.

2. To enable soil moisture to penetrate the soil and be available for crops the following year.

It is important that this process be accomplished in August or September, rather than later in the season. Deep tillage as late as November will have very little effect on control of quack grass. By this time, the quack grass roots have been built up with plant food to a point where they can overwinter readily. However, if killed in August or September before the roots have a chance to store food reserves, the winter freezing will kill the greatest majority of them.

During a wet growing season plants have sufficient moisture to maintain proper growth. However, during a dry growing season, the effect of deep

tillage in conserving moisture and preventing runoff makes water available to growing plants which results in many cases in the difference between an outstanding crop and a crop failure.

It is important that deep tillage tools **not** be used when the subsoil is wet. Consequently, deep tillage should not be practiced in the spring as this will have a tendency to "puddle" the soil and do more damage than good.

## Summary

It is being recommended to sugar beet growers in Michigan that they prepare their seed beds with a minimum of operations. These are to include, where possible, the use of deep tillage tools in August or September to break up plow sole or other compacted areas to the greatest depth possible; to spring plow with a leveling tool or mulcher attached to the plow and to plant immediately after plowing, without further working of the soil.

In a majority of cases this procedure has resulted in less incidence of disease, better emergence, fewer weeds and greater yields. In no case have yields been depressed by use of the tillage methods described.

## Literature Cited

(1) COOK, R. C.
1950. Tillage practices and sugar beet yields. Proc. Amer. Soc. Sugar Beet Tech., pp. 286-293.

(2) BAVER, L. D.
1948. "Soil physics," P. 270, New York, John Wiley and Sons.

# An Improved Method of Applying Fertilizer to Sugar Beets

M. G. Frakes and H. L. Draher[1]

It is necessary, in the eastern area, to use a complete fertilizer with sugar beets. Experience has shown that the fertilizer is more efficient when applied at the time of planting. It has also been shown that "banding" the fertilizer close to and below the seed is much more efficient than "broadcasting" or drilling in ahead of the planter operation.

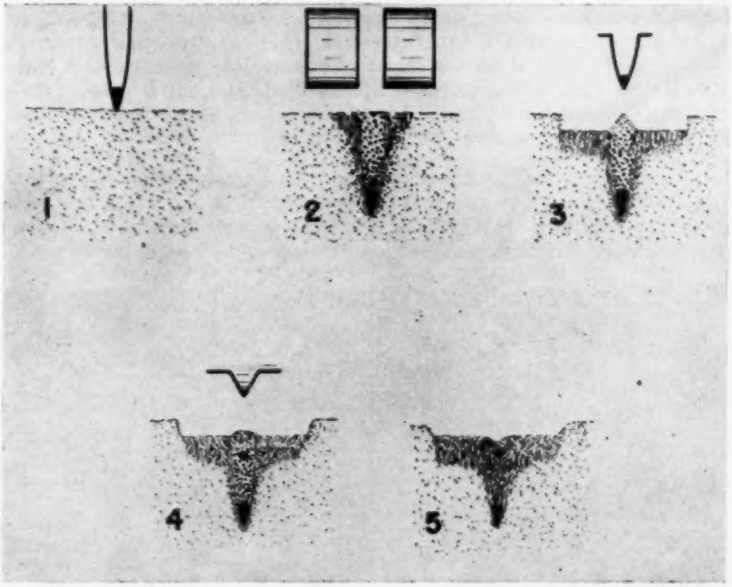


**Figure 1.—Shows diagramatically the method of fertilizer and seed placement accomplished with the new drill. 1. Fertilizer placed 4 inches deep. 2. Dual press wheels firm soil on both sides of fertilizer placement. 3. Seed is planted directly over fertilizer. 4. V-shaped press wheel directly over seed. 5. Results in good seed-soil-fertilizer-moisture relationship.**

Dr. R. L. Cook (1)[2] has shown that when fertilizer was placed directly with the seed or directly under the seed, the plants actually emerged from the soil quicker than they did when the fertilizer was placed some distance from the seed. He found that it was possible to see a difference in emergence when fertilizer was placed 1½ inches from the seed as compared to ½ inch. Dr. J. F. Davis (2) has found that 400 pounds of fertilizer directly

[1] Agricultural Research Director and Research Assistant, respectively, Michigan Sugar Company, Saginaw, Michigan.
[2] Numbers in parentheses refer to literature cited.

underneath onion seeds on muck soil were as efficient as 1,000 pounds of fertilizer broadcast prior to seeding. All conventional planters place the fertilizer in a band two inches to one side and two inches below the seed.

It has been shown that by placing a small quantity of fertilizer in direct contact with the seed an increased emergence and subsequent rate of growth will result. Since 200 pounds is the limit which can safely be placed in direct contact with the seed, and since this is not enough to bring a crop through to a maximum yield, methods other than the above for placing fertilizer must be used.

A new drill was developed and built, using Milton seeding units, whereby fertilizer was placed three inches **directly below** the seed. The fertilizer was placed in a restricted band by means of double disc openers followed by dual press wheels which exert pressure on each side of the fertilizer band. The seeding units follow, placing the seed dirctly over the fertilizer. These then are followed by V-shaped rubber press wheels directly over the seed. See Figure 1.

This method of placing fertilizer directly underneath the seed and then pressing around and directly over the seed results in more favorable seed-soil-fertilizer-moisture relationships. This compressed area will tend to draw moisture for better germination of seed as well as better utility of

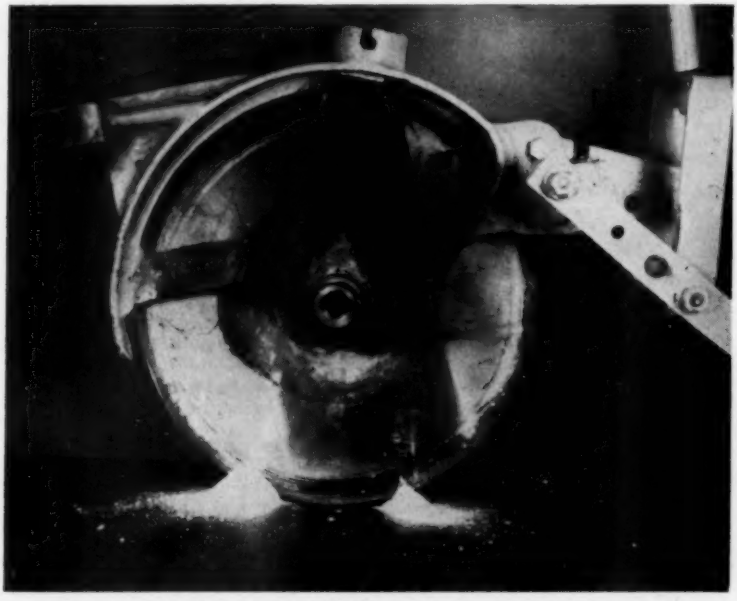

**Figure 2.—Showing detail of fertilizer placement unit. Note that greatest portion of fertilizer falls *ahead* of disc center to insure restricted band placement.**

fertilizer. The seedling rootlet grows directly into the fertilizer which is thus used more efficiently than when placed a considerable distance from the seedling root.

It is necessary to place the fertilizer as deeply as possible with a minimum disturbance of the seed bed prior to planting of the seed. This is accomplished by a dual disc opener through which fertilizer passes and is placed in a very restricted area. See Figure 2.

The drill itself is designed to raise and lower by means of a hydraulic lift. The fertilizer drive mechanism ceases to operate when the drill is raised from the ground. The Milton seeding units are selfdriven and cease to operate when the drill is raised. See Figure 3.

## Results

The drill was tested under many varying conditions ranging from very loose soil resulting from minimum seed bed preparation to well packed, firm seed beds. Fields ranged from light sandy loam soils to heavy clay soils and included fields with relatively poor drainage as compared with

**Figure 3.—Showing new drill. Note fertilizer placement discs, dual press wheels, Milton seeding units, V-shaped press wheel.**

good drainage. Also, fields containing high organic matter as compared with fields low in organic matter were included. Early plantings were made was well as late plantings and the results obtained from the use of the drill

were satisfactory in every case. The drill was used side by side in the same field with the conventional type drill.

Some of the results obtained are as follows:

1. Pre-Thinning Stand

| | |
|---|---|
| New Drill | 50.1 Beet Inches per 100 Inches |
| Regular Drill | 31.1 Beet Inches per 100 Inches |
| Increase | 19.0 (62 percent better stand) |

These figures are an average of 48 different comparisons of counts made in fields where the new drill and the regular drill was used side by side. These counts were made before thinning and indicate a 62 percent average increase in the number of beet-containing inches per 100 inches in the favor of the new drill. It was noted in many cases that these beets not only came up earlier but their initial growth was more rapid than those planted in the regular manner. In several instances labor went into the field and worked every other four-row strip planted with the new drill and came back a week later to work the remaining alternate four-row strip which had been planted with the regular drill.

It was observed that emergence of sugar beets when planted with the new drill was so superior that the last few fields were planted with special plates in which beets were space-planted. Plates were used by which three seeds were dropped one inch apart at 12-inch intervals. In almost every case we obtained too many beets and it was necessary that they be thinned.

2. Yields

| | |
|---|---|
| New Drill | 15.579 Tons per Acre |
| Regular Drill | 13.180 Tons per Acre |
| Increase | 2.399 Tons per Acre |

These figures are an average of 20 comparisons in which the new drill was used side by side with the regular drill. When harvesting the beets on some of the fields, it was found that there was a noticeable difference in the number of "sprangly" roots. There were a greater number of "sprangly" roots in those plots planted with the regular drill than in those planted with the new drill. This phenomena did not extend to all of the fields tested but to a great many of them. It is obvious that the ability of the small plant to extend the taproot deep into the subsoil is a very decided advantage in the later growth and development of that plant.

3. Harvested Stand

| | |
|---|---|
| New Drill | 94.70 Beets per 100 feet |
| Regular Drill | 77.95 Beets per 100 feet |
| Increase | 16.75 Beets per 100 feet |

These figures are an average of 20 comparisons and indicate a substantial increase in the number of marketable beets per 100 feet of row in favor of the new drill. This may result frome one of two facts: that the stand

is more uniform so that labor can leave a better stand originally; or that there was less dying out of beets between the blocking and thinning and time of harvest. It was found, on an average of 32 comparisons, that the sugar content showed an increase of .40 and purity of the beets showed an increase of 1.16.. Coupled with an increase of 2.399 tons per acre, this indicates an increase of 633.75 pounds of sugar per acre (recoverable) in favor of the new drill over the regular drill.

4. Varying Fertilizer Placement with New Drill

| | |
|---|---|
| Directly under seed (2½") | 23.918 Tons per Acre |
| 2" beside and 2½" below seed | 21.681 Tons per Acre |
| Increase | 2.237 Tons per Acre |

These figures are an average of four comparisons. These tests were conducted with the new drill, in order to compare the placement of fertilizer directly below the seed as compared with 2 inches beside the seed, when the fertilizer was placed at the same depth in each case. In the previous comparisons with the new drill with fertilizer placed directly beneath the seed as compared with the regular drill which places the fertilizer beside the seed, it was found that the regular drill does not place the fertilizer nearly as deep as does the new drill. These figures, however, indicate that regardless of depth of fertilizer it would appear advantageous to have it placed directly beneath the seed.

5. Difference due to Field Fertility

| | Fields Ave. Over 15 Tons per Acre[1] | Fields Ave. Under 15 Tons per Acre[2] |
|---|---|---|
| New Drill | 17.96 | 12.02 |
| Regular Drill | 16.00 | 8.96 |
| Increase | 1.96 (12.3%) | 3.06 (34.2%) |

[1] Ave. of 12 fields
[2] Ave. of 8 fields

In breaking down the data into those fields which averaged more than 15 tons per acre as compared with those fields averaging under 15 ton per acre, it is interesting to note the following: That of the 12 fields averaging more than 15 tons per acre (based on yield obtained from the new drill) the increase was 1.96 tons per acre, or 12.3 percent increase, as compared with 3.06 tons per acre, or 34.2 percent increase, on those fields which averaged less than 15 tons per acre. These tests are perhaps not extensive enough to draw any definite conclusions; however, they seem to indicate that we could probably expect greater increases by the use of the new drill on those fields which produce 10 to 12 tons per acre than we can on those fields which produce 17 to 18 tons per acre.

Most of the fields reported in this paper received fertilizer applications of 400 to 550 pounds per acre. The same amount of seed (5 pounds per acre) was applied with both drills in all cases, as well as the same amount

of fertilizer. All fields were planted in 28-inch rows. There was no supplemental irrigation on any of these fields.

In order to determine whether or not we would obtain any damage by placing fertilizer directly underneath the seed if we used a high nitrogen-containing fertilizer, we ran a series of tests in which 600 to 900 pounds of 8-8-8 fertilizer were placed in bands directly underneath the seed as described. In no instance did we find any damage to germination, emergence or subsequent growth of the sugar beets.

It should be pointed out that in Michigan in the area in which these tests were conducted, there is sufficient rainfall in most seasons for growth of plants and supplemental irrigation is very seldom used. In those areas where supplemental irrigation is required and natural evaporation of moisture is greater than perculation, it may be that some injury may occur to germinating sugar beet seedlings.

Under Michigan conditions of ample spring rainfall, we encountered no detrimental effects from placing fertilizer, which in most cases included borax, in a restricted band 2½ inches directly underneath the seed. In all cases, germination was faster and emergence quicker where seed was planted with the new drill. The results presented in this paper suggest that further extensive trials are warranted. The Michigan Sugar Company has purchased 35 of these drills for use with the 1954 crop and will make them available on a rental basis to growers for planting.

The Milton seeding units are manufactured by Harbison-Paine, Inc., Loveland, Colorado. The remainder of the drill with fertilizer units is manufactured by Palsgrove Manufacturing Company, Canal Winchester, Ohio.

## Literature Cited

(1) COOK, R. L.
1951. Effect of fertilizer on sugar beet stands. Proc. 6th Reg. meeting, Amer. Soc. Sugar Beet Tech., Eastern United States, pp. 124.

(2) DAVIS, J. F., CUMINGS, G. A. and HANSEN, C. M.
1951. The effect of fertilizer placement on the yield of onions grown on an organic soil. Mich. Agr. Exp. Sta. Quart. Bul. 33: 249-256.

# Preventive Weed Control—Methods and Equipment

JOHN T. MALETIC[1]

Weed control on the farm costs less when sources of weed infestation are eliminated. The United States Department of Agriculture has estimated the average annual loss in the United States due to weeds at five billion dollars (1)[2]. The loss has been described by Sylwester and reported by Anderson (1), as being the greatest single loss after soil erosion facing agriculture today.

These losses can be reduced by consistent programs of weed control on non-crop lands. In the western states, about 6 percent of the land area within irrigation projects is made up on non-crop lands such as canals, laterals, drainage ditches, rights-of-way, farmsteads, farm roads and farm ditches. This comparatively small area plus public rights-of-way and fence rows probably are sources of most weed infestation of irrigated fields. Not to be overlooked, however, are watershed areas which contribute water supply to projects. Weedy plants on watersheds above irrigation projects shed seeds into the water and thus they reach irrigated fields. Consequently, practical control measures should include watershed areas along with ditchbanks, county and state roads, fence rows, and other non-cropped land.

Benefits of preventive weed control programs are not restricted to savings on the farm. General benefits of roadside and utility line spraying programs listed by Sylwester (2) include:

> 1. Eradication of noxious weeds, 2. Easier mantenance, 3. More permanent control, 4. Elimination of traffic hazards, 5. Elimination of health hazards, 6. Improved utility services, and 7. Improved beauty.

Experience with weed control programs along irrigation and drainage ditches on Reclamation projects has shown that other benefits are:

> 1. Conservation of water by decreasing evapo-transpiration and seepage losses; 2. reduction of operation and maintenance costs by facilitating inspections, preventing ditch breaks, decreasing siltation in ditches, allowing more accurate measurement of water, and prevention of erosion.

A major benefit of ditchbank weed control programs is the prevention of weed seed spread by irrigation water. To determine amounts of weed seeds carried by irrigation water, Wirth (3), placed a flat screen in a farm turnout on the Kendrick Irrigation Project, Wyoming, and collected weed seeds for a period of one hour. The test was conducted in September, 1948. The ditchbank for about one-half mile above the turnout was predominantly covered with sweet clover and Russian thistle. The total seed count for the hour indicated 326 seeds consisting of the following: Sweetclover—306, Downy Brome—1; Russian Thistle—3; Wild Salsify—2; and Wild Lettuce—14. Work done by Hope and reported by Bruns and Rasmussen

---

[1] Regional Soil Scientist, Region 7, Bureau of Reclamation, Denver Federal Center, Denver, Colorado.

[2] Numbers in parentheses refer to literature cited.

(4) shows that the flow in an irrigation ditch could carry a weed seed load which amounts to a deposition of 170,800 seeds per acre of land in one 6-inch irrigation.

The influence of underwater submergence on the viability of weed seed has been investigated by Bruns and Rasmussen (4). They concluded:

> 1. Germination of Canada thistle seed after removal from the water increased from 53 to 92 percent during the first two months. The average germination of the seed dropped below 6 percent after ten and eleven months when water temperature was high. However, germination increased again as water temperature declined. 2. The germination of Russian Knapweed seed increased from one-half percent to 57 percent after two months of fresh-water storage and then fluctuated between 1 and 30 percent with a rise and fall in water temperature during the remainder of the storage period. 3. No germination of poverty weed seed occurred before two months of fresh-water storage. The germination of this weed increased to a peak of 43 percent after seven months, but dropped to less than 3 percent after 10 and 11 months. Germination again increased as water temperature declined. 4. Germination of morning glory seed fluctuated between .2 and 9 percent except for a peak germination of 17 percent after 18 months of storage. 5. White top seed either germinated or disintegrated appreciably in fresh-water storage and 98 percent or more of the seeds were no longer viable after 6 months.

From the above, itis apparent that irrigation water is an effective agent for disseminating weed seeds.

The most important element of preventive weed control programs is a consistent year-by-year application of adapted weed control practices directed toward eventual replacement of weeds with desirable vegetation. The control program should be developed after a survey of the entire weed problem. This includes type, distribution and extent of weed infestations; soil conditions, topography and drainage of infested areas; accessibility of infestations; sources and quality of water supply; cropping patterns adjacent to infested areas; damages done by weeds; and the justifiable expenditure for control. An analysis of the foregoing factors determines the methods and equipment best suited to tackle a particular problem.

Preventive weed control on ditch banks employs mechanical, chemical and vegetative methods of control. General costs of these various methods based on Reclamation irrigation project experience are given in Table 1. These are general costs and may vary widely depending upon conditions and the size of ditch banks. The details of weed control techniques used on irrigation systems have been described by Balcom (5).

**Table 1.—Some Typical Weed Control Costs for Irrigation Systems.**

| Method | Cost Per Unit | Method | Cost Per Unit |
|---|---|---|---|
| Burning (Hand Labor) | $50.00/mile | Spraying 2,4-D (Annual Weeds) | $ 5.00/acre |
| Burning (Power Equipment) | 7.00-28.00/mile | Soil Sterilization (CMU) | 140.00/acre |
| Mowing (Power Mower) | 9.00/mile | Soil Sterilization (Borascu)[1] | 150.00/acre |
| Spraying 2,4-D (Willow Control) | 13.00/Acre | Grass Planting | 16.00/acre |

[1] Concentrated Borascu

Principal mechanical control methods for annual and biennial weeds are burning and mowing, preferably used when ditch banks traverse cropped areas which are susceptible to injury by 2,4-D or other chemicals. Mowing is generally used on easily travelled, smooth ditch banks while burning technique is used on rough, rocky irrigation ditch banks. An advantage of both methods is that their timely application will prevent the spread of weed seeds. The plans and specifications for various types of burning equipment used on Reclamation projects have been compiled by Bowser (6).

The wide variety of weed control chemicals and application methods changes rapidly with results of continuous widespread research. A compilation of chemical methods which have been satisfactorily used is given in Table 2.

**Table 2.—Chemicals Used to Control Land Weeds on Irrigation Systems.**

**I. Selective Herbicides**
1. 2,4-D Ester, Amine (1 to 5 lbs. acid/A)
2. 2,4, 5-T (1-5 lbs./Acre)
3. Sinox (1 gal. in 100 gals. water at rates 80-120 gals./A)
4. TCA (Perennial grasses 80-150 lbs./A; Annual grasses 20-60 lbs./A)

**II. Contact Herbicides**
1. Water-soluble: sodium chloride, calcium chloride, ammonium sulfamate, sodium chlorate, sodium arsenite, sulfuric acid.
2. Diesel Oil Spray (120-150 gals./acre—several applications per season to kill weedy grasses)
   (a) Pentachlorophenol, dinitro secondary butyl and amyl phenols (4 lbs. in 100 gals. oil)
   (b) Dow General, Sinox General, or Chipman General (1¼ lbs. in 100 gals. oil)
4. Aromatic Oils
   Shell weedkiller 20, Standard weedkiller 2, Richfield weedkiller A, and General Petroleum weed exterminator oil (30-50 gals./A)
5. Oil Emulsions
   (a) 4 lbs. Pentachlorophenol, 6 gals. Diesel Oil, 4/5 lbs. wetting agent, in 94 gals. of water
   (b) 2-3 pints Sinox, Dow, or Chipman General, 15-30 gallons oil made up to 100 gals. with water.

**III. Soil Sterilants**
1. Sodium chlorate (6 lbs./sq. rod)
2. Borax (30 lbs./sq. rod)
3. Borascu (30 lbs./sq. rod)
4. Concentrated Borascu (15 lbs./sq. rod)
5. Polybor-chlorate (1½ lbs. in 1 gal.—covers 50 sq. ft. or 8 lbs./sq. rod)
6. CMU (10-60 lbs./acre)

**IV. Soil Fumigants**
1. Carbon disulphide
2. Shell DD
3. Chloropicrin
4. Ethyl Dibromide

Equipment used for weed spraying is described by Bowser (6), Akesson and Harvey (7) and Price, et al (8). After reviewing the various types of spraying equipment used on Reclamation irrigation projects, Graham (9) developed the following specifications for spray equipment:

**Spray pressure**—75-150 pounds per square inch; 100 psi generally adequate.

**Pumps**—Capable of supplying required volume at 100 pounds

per square inch . . . tendency is toward rotary or turbine type pumps. A self-priming pump is preferred and should be available for filling the tank.

**Types and sizes of spray tanks**—noncorrosive, easily cleaned, no leakage. Tank size depends on pump capacity and water availability. For a pump delivering 30 to 50 gallons per minute the most economical capacity is 300 to 500 gallons . . . minimum tank capacity 10-15 gallons for each gallon per minute required by the spray boom.

**Agitator**—A requirement of all spray units; should operate while workers fill the tank and while spraying.

**Booms**—1¼ inch pipe for booms with capacities up to 18 gallons per minute; 1½ inch for larger capacities; boom length depends on spraying conditions.

**Nozzles**—Uniformly spaced 12 to 18 inches and set at a height for double coverage; nozzles set on side of boom to prevent plugging; shutoff valve in supply line leading to boom where it can be easily reached; relief valve installed between pump discharge and stop-cock; pressure gauge installed between pump discharge and stop-cock.

**Handgun**—Should be on all equipment.

Although equipment meeting these specifications has been found to operate satisfactorily, many enginering improvements still remain to be made. Anderson (1), in discussing chemical weed control equipment, lists the following challenges to the agricultural engineers.

> The equipment should more satisfactorily resist corrosive, abrasive and other deleterious effects of a wide range of weed and other farm control chemicals. Simpler, more effective, and more economical pumps should be designed. Functionally designed long-life nozzles with greater attention to particle size and pattern should be developed. Working parts should be arranged into more compact and practical mountings for tractors in the case of tractor-mounted, tractor-powered units. The use of directional spray equipment and shields to protect the pay crop should be develpoed further.

Experience on Reclamation projects has aptly demonstrated that weeds on irrigation systems can be controlled with least expense by establishing stands of desirable grasses. In Region 7 of the Bureau of Reclamation, it takes about five years to establish solid grass stands with such grasses as smooth brome, crested wheatgrass, western wheatgrass, intermediate wheatgrass and sand love grass. The grasses are planted in mixtures. A 50-50 mixture of smooth brome and crested wheatgrass has proven highly successful in south central and western Nebraska. While grasses are being established, undesirable vegetation is reduced by spraying 2,4-D. Then following establishment of grasses, ditch banks can be pastured under a controlled grazing program. In this way, weed control costs become and remain minimized . . . beneficial use of the ditch banks is made . . . weed seeds are not spread . . . and erosion is reduced.

## Literature Cited

(1) ANDERSON, E. D.
1952. Engineering developments and challenges in chemical weed control. Ag. Eng. Aug. 482-486.

(2) SYLWESTER, E. P.
1951. Control of roadside weeds and brush. Weeds 1:1:17-24.

(3) WIRTH, L. D.
1949. Weed seed trap considerations. Minutes of the fourth annual weed control meeting, Bureau of Reclamation, United States Department of the Interior and the Bureau of Plant Industry Soils, and Agricultural Engineering, Department of Agriculture; Bozeman, Montana, February 5, 7 and 8, 1949. (Processed). 42-47.

(4) BRUNS, V. F., and RASMUSSEN, L. W.
1953. The effects of fresh water storage on the germination of certain weed seeds. Weeds II-2; 138-147.

(5) BALCOM, R. B.
1949. Control of weeds on irrigation systems. Bureau of Reclamation, United States Department of the Interior, 1-140.

(6) BOWSER, C.
1953. Weed control equipment used on irrigation systems. Operation and maintenance equipment and procedures, Release No. 3. Bureau of Reclamation, 5-7.

(7) AKESSON, N. D., and HARVEY, W. A.
1948. Chemical weed control equipment. Circular 389, California Agricultural Experiment Station, Berkeley, California. 1-43.

(8) PRICE, F. E., LUNDE, R. N., BURSIK, J., and FREED, V.
1946. Recommendations for weed spraying equipment. Station Circular 170. Agricultural Experiment Station, Oregon State College, Corvallis, Oregon.

(9) GRAHAM, C. J.
1947. Equipment for ditch bank weed control. Minutes of Bureau of Reclamation Weed Control Meeting, Portland, Oregon, February 8, 10 and 11, 1947. United States Department of the Interior, Bureau of Reclamation (Processed). 67-71.

# Planting for Machine Thinning

L. A. LOHMEIER[1]

Since the seedbed is the environment for the seed and subsequently the seedling, the importance of the proper preparation of this seedbed can not be overemphasized. If climatic and soil conditions permit, fall plowing should be done to obtain the mellowing effect of winter weather which does much toward producing a desirable seedbed for early planting.

In irrigated areas use of a two-way plow will leave the ground in a more level condition because back furrows and dead furrows are eliminated. Clods resulting from fall plowing can be eliminated by use of a land packer or roller. Air pockets in the soil can be removed by using a harrow. Soils which tend to pulverize should not be worked until shortly before planting time. An Eversman land leveler will pack the topsoil enough to maintain good contact with subsoil moisture, and at the same time leave the finished seedbed in such a condition that only slight depressions left by the press wheels of the drills will be visible.

Since obtaining a uniform emergence of seedlings is so essential to the successful use of the mechanical thinner, the importance of the planter and its proper use can not be stressed too often. It is desirable to use the John Deere 66, the Milton or the International—all so-called precision planters—so that a mechanical thinner can later be used. They are "so-called" because there are many factors beyond the control of the planter which determine a uniform stand.

To depend upon the planter's mechanisms alone to produce an even distribution of seeds and for even distribution as to unvarying depths and unvarying intervals, is expecting far too much from any mechanical device completely severed from human influences. Human influences, of necessity, must enter into the successful performance of a beet drill. For the speed at which a drill is operated, and the care that the mechanisms of the planter receive during its operation are the controlling factors in obtaining maximum performance from any beet drill.

If a planter is operated at a maximum speed of 2½ miles per hour, the seed will be more evently distributed. This was proven conclusively by a recent study made by the Beet Sugar Development Foundation. This study on percent of cell fill in relation to speed showed that, when a planter was driven 2½ miles per hour the cell fill was 112 percent, but as the speed of the planter was increased the percent of cell fill decreased. When the planter was being operated at 5 miles per hour, the percent of cell fill decreased to 82 percent.

A study was also made as to the importance of the use of a new seed plate in comparison to an old one relative to cell fill. In each case the percent of cell fill where the new plates were used was much greater—in some cases as much as 18 percent.

---

[1] Superintendent of Agriculture, the National Sugar Manufacturing Company, Sugar City, Colorado.

The size of seed plates in relation to the size of seed used will also determine the percent of cell fill. If a 7 to 9½/64 inch seed is to be planted, a plate with a cell diameter of 11/64 inch should be used. By using a 1½/64 inch larger cell than your largest seed, you eliminate the danger of damaging your seed germ, and also increase your cell fill.

Seeding rates should be determined by seeds per foot rather than by pounds per acre. In the National Sugar Company territory in southern Colorado, twelve seeds per foot is the recommended seeding rate. This would be equivalent to 6½ pounds to 7½ pounds per acre when 7 to 9½/64 inch seed is used. If this seeding rate is used, loss from frost, insects and seedling diseases will be minimized. Also, better germination will provide a uniform emergence so necessary for the successful use of a mechanical thinner.

Most of the beet planters on the market today will distribute the seeds in a uniform pattern if they are driven at a rate of not more than 2½ miles per hour, if the proper cell plates are used and if the seed bed is in a level, well mulched condition. Bunching of seed and subsequent failure to drop seeds are results of increased speed. This has been proved again and again by tests we have made. In fact, our tests have shown that the total number of seeds in 100 inches of row will decrease as much as 30 percent when the speed is increased from 2 to 4 miles per hour.

Speed is not the only determining factor for uniform emergence as depth of planting is equally important. Many beet growers have a habit of using only one planting depth regardless of time. The average percentage of seedling emergence can be improved if the importance of the planting depth in relation to planting time is stressed (1)[2].

This past year on the Sugar Company farm at Sugar City the beets were planted with a 6-row Milton hang-on planter. However, some difficulty was experienced in obtaining uniform compaction immediately above the seed; so on one of the units the press wheel brace was extended up 4 inches and the spring tension arm was made 2 inches longer. This lowered the packer wheel 1½ inches; thus the bottom of the packer wheel was only 1 inch above the bottom of the disc opener. One of the dual packer wheels was removed and 1½ inch spacers installed. A drag chain was attached to roughen up the depressions left by the remaining wheel, which ran immediately above the seed row. Following emergence, stand counts were taken. In the one row where increased pressure and the single wheel were used the average stand count was 38 beet-containing inches and in the other five the average stand count was 30. This experimental unit was used on 75 acres of beets and seeds planted with it germinated so much faster than the seeds in the other five rows that this row was used as a guide row for the first cultivation. Our Milton drill set at a depth of 1½ inches was attached to the back cultivator bar and a cultro set at the same depth was attached to the front bar. This additional mulching of the ground immediately ahead of the planter was for the purpose of improving the capillary action of the subsoil moisture.

---

[2] Numbers in parentheses refer to literature cited.

At the present stage of planter development any of the planters used in our particular locale are adequate if they are properly operated and the seedbed is properly prepared. However, a planter can do no more than place seeds at a fairly uniform depth and at fairly uniform intervals in a seedbed so prepared that it offers an ideal environment for the germinating of every seed unit. The end result is a uniform stand so necessary for successful thinning.

## Literature Cited

(1) McBIRNEY, S. W.
1948. Improvement of sugar beet seedling emergence by planter development. Proc. Amer. Soc. Sugar Beet Tech. pp. 230-231.

# Status of Spring Mechanization in the Michigan Area

M. C. HENDERSON[1]

The increasing shortage of satisfactory labor and the constantly rising costs pertaining to it make it imperative that some means be devised and used to reduce the amount of labor required to block and thin sugar beets and the cost of growing the crop. This is emphasized in the eastern beet area where labor sources are at a greater distance, causing high transportation costs.

There are several approaches to the reduction or elimination of labor which are available. Some of them are:

1. Use of monogerm seed.
2. Better methods of seedbed preparation for improved emergence and fewer weeds.
3. Improved methods of planting and use of fertilizer.
4. Chemical weed control.
5. Use of mechanical devices to control weeds and obtain the desired stand of beets.

It is obvious that one, or any combination of these approaches, would aid in achieving our goal—**elimination of spring labor.** If we had commercially available monogerm seed, space planting and positive chemical weed control, it is conceivable that our goal could be accomplished. Although there are some encouraging results along these lines of research, there are none which are 100 percent effective when used in the field. Until such time as these approaches become perfected, it is imperative that the best use be made of the best means available at present.

In the Michigan area, we are concentrating our efforts toward the use of a down-the-row thinner using the principle developed by the Great Western Sugar Company and commonly known as the "Windsor System" (1)[2]. A very comprehensive and intensive educational program is being followed with selected growers and the fieldmen who serve them. The actual operation of the machine is carefully supervised and a company representative works directly with each chosen grower during the entire operation. Parts of each field are unworked so each farmer and his neighbors can see and compare the results accomplished. The following year different growers are selected and the program repeated. The number of these growers is held down to where it is possible to give each one the attention and assistance necessary to accomplish the job.

The machine used is the standard 4-row trail type. However, it is modified so that it is attached to the rear of the tractor and operated by means of the tractor hydraulic system. The unit remains ground-driven.

In conjunction with this program, we are continuing research in an attempt to develop machines which may do the same job easier and better.

---

[1] General Field Manager, Michigan Sugar Company, Saginaw, Michigan.
[2] Numbers in parentheses refer to literature cited.

In 1953, we tested a simple variable speed, counter-rotating, double head machine based on the principle developed and described by George W. French (2).

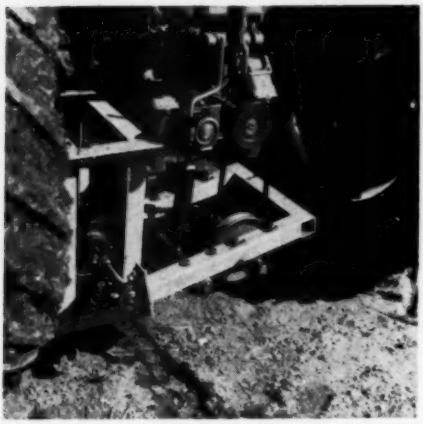

**Figure 1.—A variable speed unit attached to a John Deere "40" tractor for powering a dual head, counter-rotating, 4-row beet thinner.**

The variable speed unit is standard for all makes and models of tractors having power take-off assemblies. This unit is fitted to various models by bolting to a plate which will in turn fit a given model tractor. See Figure 1.

The individual counter-rotating, dual head gear boxes are all standard and are attached to a cultivator bar by means of regular clamps. Interchangeable mounting brackets are used for varying types of clamps and cultivators. Depth control is obtained by means of standard cultivator bar depth gauge wheels. See Figure 2.

There is an indefinite number of combinations of size and number of teeth which may be used on one or both heads. The variable speed unit will alter the speed of the rotating heads from a cut every six inches to a continuous cut in which everything may be taken out. Further changes in speed may be accomplished by shifting gears of the tractor.

It is possible to use one head with small teeth (16-tooth-½ inch) and completely thin beets once over the field. Under good conditions, labor savings up to 82 percent have been obtained. Further extensive tests are planned for 1954 before this machine will be recommended for large scale use.

In order to avoid confusion in having "lefts" and "rights" in teeth, depending on the direction of rotation, a new type tooth was designed. This tooth works equally well regardless of the direction it travels. The teeth shown in Figure 3 were made up for preliminary testing. An improved type will be manufactured this year. Subject to further testing, it may be possible that only one size and shape of tooth may be necessary for the thinning operation under varying conditions when used with a

**Figure 2. — A dual-head, counter-rotating beet-thinning unit. Note simplicity of attachment to cultivator bar and depth control.**

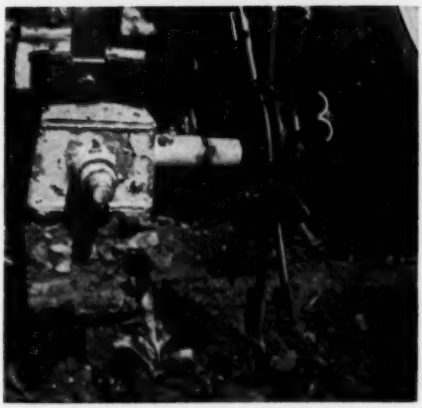

**Figure 3.—A beet thinning head showing the "universal" tooth which operates well regardless of direction of rotation.**

variable speed thinner. Excellent results were obtained in 1953 using this "Universal" tooth followed by the spring tine teeth going in the opposite direction on the second of the dual heads.

This machine is very simple to mount and remove from any tractor. Four bolts hold the variable speed system and cultivator bar clamps hold the thinning units. There is ample room on the cultivator bar for cultivating tools if these are desired. The thinner is being manufactured by the Palsgrove Manufacturing Company, Canal Winchester, Ohio.

### Literature Cited

(1) ANDREWS, LYMAN H.
1952. Planting, mechanical thinning and weeding. Proc. Amer. Soc. Sugar Beet Tech.; pp. 603-608.

(2) FRENCH, GEORGE W.
1952. A report on tests of mechanical weeding and thinning equipment in Michigan. Proc. Amer. Soc. Sugar Beet Tech.; pp. 586-592.

# Thinning Trials in Eastern Montana

E. G. Eckroth[1]

Progress made in mechanical thinning of sugar beets has been significant and the process is here to stay. It has been demonstrated beyond a doubt that, when properly done, a satisfactory job can be performed. Mechanical thinning has saved many fields which in the past would have been torn up because of weeds, disease, or the inability of labor to get the field worked in time. Some mechanical thinning is becoming a necessity as the labor supply is diminishing yearly, which means we must increase our production per man hour. Since an increase in acreage is in prospect, less labor will have to care for more acres than ever before.

In 1953 a replicated test of 6 row plots the length of the field was laid out. This field had been replanted due to severe frost damage. The germination stand was 24 percent, which was ideal for thinning with the Silver thinner, using the twice over method. Three thinning machines were used: Silver thinner, Pierce row crop blocker and the French thinner. Special interest was shown in the French thinner because of its counter-rotating double head principle, operated from the power take-off. It was thought that the 8- and 16-blade Silver cutting heads could be used at the same time to replace the twice-over system. However, after some experimentation, it was found that satisfactory performance could not be obtained. Plans for the test were changed and the French thinner was then used in four treatments consisting of the use of the 8-blade Silver head in first gear, and the 16-blade Silver head in first gear, with both of these driven at the same rate of speed; and these same cutter heads used in the same way with the tractor driven in second gear at a faster rate of speed. Each of these four treatments was followed by short handle hoe thinning. The Pierce row crop blocker, a ground-driven thinner mounted on the front tool bar, followed by short handle hoe thinning, made up one treatment. The Silver thinner used in the twice-over method, with no hand labor thinning, made up another treatment. The check consisted of hand labor only. Time records were kept on all hand work.

**Table 1.—Final Results in Yield, Percent Sucrose, and Percent Stand.**

| Treatment | per 100 Ft. Final Stand | per 100 Ft. Doubles | Beets Tons | Sucrose Percent | per Acre Gross Sugar |
|---|---|---|---|---|---|
| Hand Thinned (Check) | 99 | 6 | 12.94 | 18.77 | 4,849 |
| Pierce Row Blocker | 81 | 6 | 12.56 | 18.79 | 4,718 |
| French 8-Blade, 1st Gear | 88 | 4 | 12.57 | 18.70 | 4,704 |
| French 16-Blade, 1st Gear | 96 | 6 | 12.20 | 18.84 | 4,597 |
| Silver Twice (Complete) | 124 | 28 | 12.08 | 18.68 | 4,510 |
| French 8-Blade, 2nd Gear | 85 | 4 | 13.18 | 18.41 | 4,846 |
| French 16-Blade | 88 | 4 | 12.57 | 18.66 | 4,690 |
| L.S.D. (0.05 level) | | | 1.94 | .62 | 686 |

[1] Associate Agronomist, Beet Seed Breeding Dept., Holly Sugar Corporation, Sidney Montana.

No significant differences were found between the treatments in regard to yield, gross sugar per acre or sucrose content. The final stands for all treatments were good with the one exception—the Silver thinner treatment had too much stand for the growth conditions in Montana. The heavier

**Figure 1.—Single unit of a Pierce Row Crop Blocker. Mounts on any tool bar, front or rear, with a single standard clamp for each blocker. The blocker is ground driven and has an adjustable spring tension which automatically maintains required pressure between unit and ground. Block size is determined by openings between knife blades as viewed from the side.**

**Table 2.—Thinning Time Saved Due to Use of Mechanical Thinners.**

| Treatment | Thinning Time Man Hours per Acre | Percent Man Hours Saved Compared with Check |
|---|---|---|
| | (Short handled hoe) | |
| Hand Thinned (Check) | 13.9 | |
| Pierce Row Blocker | 10.2 | 27 |
| French 8-Blade, 1st Gear | 9.0 | 35 |
| French 16-Blade, 1st Gear | 9.4 | 32 |
| Silver Twice (Complete) | 0 | 100 |
| French 8-Blade, 2nd Gear | 9.1 | 35 |
| French 16-Blade, 2nd Gear | 9.3 | 33 |

stands left by the Silver thinner were largely due to beets being quite large and the field being so wet that mud collected on the cutting knives. This allowed numerous beet plants to slide by the knives without being cut off. However, even under there adverse conditions, the completely mechanized treatment compared favorably with the other treatments in yield. In the final stands the Silver twice-over treatment had approximately five times more doubles than the average of the other treatments.

Considerable time was saved where short-handled hoe thinning followed some form of mechanical thinning.

In comparison with the hand thinned check, an average of 32 percent thinning time was saved where short handle hoe work followed mechanical thinning. The Pierce row blocker and the four French thinner treatments were similar in effect on stand reduction, and therefore in thinning time required per treatment.

## Summary

It is possible to obtain the same beet and sugar yields with mechanical thinning methods as with the hand thinning methods.

This test also shows that mechanical thinning gives a great saving in man hours per acre and this should definitely result in a labor cost saving.

Even though the Silver "Twice-Over Method" (completely mechanically thinned) had approximately five times as many doubles as the other treatments, it still compared favorable in yield with all other treatments.

# Spring Mechanization in the Red River Valley—1953

H. A. TVEDTEN[1]

Cross cultivation, leaving a 4- or 5-inch block, has been a common practice in the Red River Valley for the past 17 or 18 years and, as a result, we have increased the average acreage handled by each worker from 7 to an average of 12.88 acres per worker in 1953 when 6,683 workers thinned and hoed 86,109 acres. The crop rotation practiced in the Valley has also been an important step toward complete mechanization of our thinning and hoeing operations.

By summer fallowing and keeping the land black the year previous to a beet crop, the growers have take care of their weed problem. When coming back to this same piece of ground the third or fourth time in the customary three- or four-year rotation plan, there just are not enough weeds in the field to make hoeing a problem.

From experience gained on our company farm at East Grand Forks during the past seven years, we have proven to ourselves and to many of our growers that, when a field comes to good stand and an even stand, it is a simple task to completely mechanize the thinning operation by cross-cultivating, leaving an inch and a half block. Despite unfavorable weather conditions over parts of the Valley last year we did have 5,451 acres non-thined by cross cultivation and 361 acres with down-the-row thinners. Time studies were kept on 3,363 of the 5,812 acres and we found that it took an average of 7.76 man hours per acre to hoe these fields for an average cost of $8.42 per acre. At the same time, the workers were well satisfied with their earnings, which averaged $1.085 per hour.

It was not until this past year that we had any experience with a down-the-row thinner. Although this experience is limited, we now feel that there may be a place for this machine in our mechanization program; especially in a field where there is not adequate stand to cross with a small block and still leave the necessary plant population per acre.

We know that the only factor which will keep us from getting all of our fields mechanically thinned within the next year or two is the fact that we do not have a drill that will give us the necessary positive seed distributions. The drill manufacturers have known our problem for several years now so we can only hope that in the very near future they will make a drill that will meet our needs.

---

[1] Agricultural Superintendent, American Crystal Sugar Company, Moorhead, Minnesota.

# Mechanical Thinning of Sugar Beets in the Area Served by the Utah-Idaho Sugar Company

BION TOLMAN AND RONALD C. JOHNSON[1]

## Introduction

Mechanical thinning or machine thinning of sugar beets infers the complete replacement of hand labor in the thinning process. As generally used, however, it includes machine work which reduces hand labor requirements. Closely related to machine thinning is type of seed used, type of drill used, seeding rate and cultural and environmental factors which affect germination stands.

The area served by the Utah-Idaho Sugar Company includes the following: Gunnison Valley in south central Utah; Salt Lake, Utah, and Boxelder Counties in north central Utah; the Upper Snake River Valley in southeastern Idaho; Yakima Valley, Walla Walla and Columbia Basin areas in Washington, and the Belle Fourche factory district in southwestern South Dakota and northwestern Nebraska.

## Seeding Rates, Stands and Drills

All acreage within the area covered by this report was planted in 1953 with 8-10 decorticated seed. This seed was sized so that not more than 4 percent was under 8/64 and not more than 4 percent was over 10/64. About 55 to 57 percent ranged in size from 9/64 to 10/64 and 37 to 40 percent ranged in size from 8/64 to 9/64. The average number of seed units per pound was from 37,000 to 38,000. Average seeding rates ranged from 8 to 10 seeds per foot with the majority running closer to the 10 seeds per foot rate.

The 8-10 processed seed had an average germination of 90 percent and germination tests showed an average of 57 percent singles. Field counts following some of our better drills showed an average of about 347 beet-containing inches in 100 feet of row. Sixty-four percent of these inches contained single beets.

Some field trials were also made using monogerm seed which had been decorticated and sized 8-10. When planted in the same drills as those referred to above, the inches containing single beets increased to an average of 89.6 percent. This indicates that the better of our modern drills do a very acceptable job of distributing seed uniformly in the row and that mechanical thinning should receive a definite impetus when monogerm seed is available for commercial planting. Details of the above work are given in Table 1.

## Machines Reduce Hand Labor Requirements

Mechanical thinning of sugar beets is no longer an experimental problem in the area served by the Utah-Idaho Sugar Company. Hundreds of farmers made it a reality during the 1953 season and hundreds more gained

[1] General Agricultural Superintendent and Research Assistant, respectively, Utah-Idaho Sugar Company, Salt Lake City, Utah.

Table 1.—Comparison of Decorticated and Monogerm Seed in 1953 Plantings[1]

| Type of Seed | Inches in 100 feet Containing Beets | Inches With Single Beets | Inches With Double Beets | Inches With 3 or More Beets | Average Maximum Gap | % Inches With Singles |
|---|---|---|---|---|---|---|
| Decorticated 8-10 | 347 | 222 | 100 | 25 | 12 | 64.0 |
| Monogerm 8-10 | 211 | 189 | 21 | 1 | 20 | 89.6 |

[1] Average counts from 14 field trials. Germination percentage of decorticated 8-10 seed was 93 percent. Germination percentage of monogerm seed was 60 percent.

sufficient experience so that they will have confidence to go ahead in 1954. Mechanical thinning has not only increased rapidly in amount during the past two years but it has improved greatly in quality. Both farmers and fieldmen are thinking in terms of the end result and not merely in terms of running over the ground with machines. The practical results are beginning to be evident. More farm families are doing their own weeding following complete machine thinning. Long-hoe thinning with no finger work is on the increase. Sugar beet laborers are showing increased output per man. This is resulting in a decrease in imported labor demands. In districts where outside labor, including Texas Spanish-Americans, Mexican Nationals and Navajo Indians, is brought in for spring work, labor needs were calculated on the basis of one worker for each 10 acres of beets planted for 1952. In 1953 needs were calculated on the basis of one worker for each 12 acres and in 1954 needs will be calculated on the basis of one worker for each 15 acres of beets. This indicates that machines are decreasing hand labor requirements.

### Machines in Use

Thinning machines in the area covered by this report consist largely of Silver thinners. There are some Dixie thinners in use and some B&P blockers and weeders. Complete thinning jobs have been done with all these machines. It is only fair to state, however, that farmers have generally done a more complete job of thinning with the Silver thinners.

### Method Most Generally Used

We have stressed the Windsor or twice-over method of machine thinning. This consists of using an 8-spoke cutting head with a 1¾-inch knife or hoe for the first time over. This operation, if done properly, cuts 50 percent of the within row area and consequently reduces the germination stand by 50 percent. The machines have available a 16-spoke cutting head with an assortment of knife or hoe sizes so that the percent removal for the second operation can be suited to the need.

### Density of Stands Left

The objective which we have established is to reduce the stand to an average of 100 to 125 beet-containing blocks. If stands have been reduced to this point by machine, then we definitely discourage any beet removal by hand labor. We do not even want any long-hoe trim on this type of stand. We want weeding only.

During the 1953 season we had machine-thinned fields left with an average of 165 to 170 beets per 100 feet of row. We worried for fear that some of these heavier stands might be too thick. Harvest results in every

case were entirely satisfactory. In the future we will discourage the removal of beets by hand labor if total beets do not run in excess of 150 beets per 100 feet of row.

### Yield Results from Machine Thinning

Direct yield comparisons between hand- and machine-thinned beets made on the experimental and demonstration farm at Shelley, Idaho, showed a yield advantage for machine thinning. Hand-thinned strips with 90 to 100 beets per 100 feet of row yielded 16.70 tons per acre. Machine-thinned beets in the same field averaging 165 beets per 100 feet of row yielded in excess of 18 tons per acre. Sugar content averaged .70 percent higher. These strip comparisons were machine-harvested and yields are based on actual beets delivered. Many other less direct comparisons were made in farmers' fields and between farmers' fields, and in every case where adequate stands, *i.e.*, at least 100 blocks of beets, were left, the comparison demonstrated the advantages of machine thinning.

### Amount of Machine Thinning Done

During the 1953 thinning season 22,758 acres were worked with machines. This compared to 11,233 acres in 1952 and 3,385 acres in 1951. Out of this total 9,322 acres were machine worked at least twice. This compares with 1,756 acres in 1952 and 327 acres in 1951. Most of this 9,322 acres was long hoe worked with a minimum of finger work. In 1953 a total of 2,910 acres was completely machine thinned. Hand labor did weeding only. This compared with zero percentage in 1952 and in 1951. A detailed report of machine thinning by districts is shown in table 2.

**Table 2.—Summary of Spring Mechanization for the Year 1953 for Various Factory Districts in the Utah-Idaho Sugar Company Area.**

| District | Total Acres Thinned | Total Acres Machine Worked | | Once Over With Machine | | Twice Over[1] With Machine | | No Hoe Trim[2] Weeding Only | |
|---|---|---|---|---|---|---|---|---|---|
| | | Acres | Percent | Acres | Percent | Acres | Percent | Acres | Percent |
| South Dakota and Nebraska | 8,133 | 4,259 | 52.36 | 2,957 | 36.35 | 1,302 | 16.00 | 1,089 | 13.38 |
| Gunnison | 5,460 | 2,826 | 51.75 | 1,746 | 31.97 | 1,079 | 19.76 | 107 | 1.95 |
| West Jordan | 7,525 | 3,437 | 45.67 | 2,036 | 27.05 | 1,400 | 18.60 | 151 | 2.00 |
| Garland | 6,809 | 2,230 | 32.75 | 1,191 | 17.49 | 1,039 | 15.25 | 8 | .11 |
| Idaho Falls | 11,517 | 2,866 | 24.88 | 1,361 | 11.81 | 1,505 | 13.07 | 862 | 7.49 |
| Washington | 31,762 | 7,140 | 22.48 | 4,143 | 13.05 | 2,997 | 9.44 | 693 | 2.18 |
| Grand Total for 1953 | 71,206 | 22,758 | 31.96 | 13,434 | 18.86 | 9,322 | 13.09 | 2,910 | 4.08 |
| 1952 | 54,650 | 11,233 | 20.55 | 9,477 | 17.34 | 1,756 | 3.21 | 0 | 0 |
| 1951 | 65,352 | 3,385 | 5.18 | 3,058 | 4.68 | 327 | .50 | 0 | 0 |

[1] Long-hoe thinning—very little finger thinning.
[2] No long-hoe trimming or finger thinning. Hand labor consisted of weeding only.

The advancement made in machine thinning in this area in 1953 as compared to 1952 was almost directly proportional to emphasis placed on the program by the various district managers and their staffs. This will no doubt continue to be an important factor. However, it is now evident that in every district there will be many farmers who will help to proclaim the possibilities and advantages of machine thininng.

# Five Years' Experience in Complete Mechanical Thinning of Sugar Beets

A. M. Watson and L. H. Henderson[1]

The shortage of satisfactory field labor during the years preceding 1949, and the mounting costs of recruiting and supplying it, forced our company to realize that it was imperative that some system be devised for the production of sugar beets without the large amount of hand labor which had been considered necessary for the thinning of the crop.

The late D. J. Roach, executive vice president of our company at that time, therefore appointed certain of our people to develop a machine which would reduce the amount of hand labor required to produce the crop. The result of this order was the G. W. thinner.

**Figure 1.—The G. W. Thinner with eight-blade head.**

This machine was used at first to precede hand thinning and proved excellent for reducing the time required to hand-thin beets. It was then discovered that the machine could be used to do a complete thinning job, eliminating hand thinning entirely. The Windsor system of complete mechanical thinning is a method of obtaining a satisfactory final stand of thinned beets by mechanical means. Our next job then was to acquaint our agricultural force with the program and educate those people with its operation. Our agricultural organization was made familiar with the program first in general meetings. Later field demonstrations were held to instruct our agricultural men in the operation of the machines and the general appearance of the fields after machine thinning. Results of mechanically thinned fields were compiled and figures showing comparative stands, comparative yields, and labor costs were made available for study.

---

[1] Manager, the Great Western Sugar Company, Windsor, Colorado, and manager, the Great Western Sugar Company, Bayard, Nebraska, respectively.

Smaller group meetings were held to acquaint various factory districts with more detailed information regarding specific conditions, stands, and knife combinations to use on any given stand. Stand charts of various kinds were developed. Results of field operations in the various districts under varying conditions were assembled and made available to all factory groups in an effort to develop a satisfactory program for all field conditions.

As the program progressed, a grower education campaign had to be organized. Many growers had become acquainted with the G. W. thinner as an aid to labor. They also were cognizant of the fact that the labor supply was dwindling each year and they therefore realized the need for a mechanical thinning program. Groups representing all G. W. growers, including beet growers association directors, were taken to our Windsor farm to view the fields of beets which had been mechanically thinned. Special thinning demonstrations were held at that time on special late planted beets.

**Figure 2.—The four rows to the right of center once over; four rows to the left of center completely machine thinned.**

Special field plots were planted late in the summer in each factory district for local field demonstrations of the machine. These demonstrations were well attended and much grower interest was developed.

Educational grower meetings were held throughout the various factory districts the following winter where films of actual mechanical thinning were shown. Results of mechanical thinning experiments and commercial fields which were mechanically thinned were given and discussed.

Following these general grower meetings, a series of small meetings limited to those growers who had expressed a genuine desire to thin mechanically were held. These meetings were for the purpose of instructing the grower in the proper methods to use in preparing his soil for mechanical thinning, and the actual counting of the stand and selection of the proper knives to produce the stand desired. Much time was devoted to the dsicussion of the necessity for and methods of weed control.

The results of our intensive program for the development of a successful practical program for thinning beets mechanically can best be observed by studying the report in Tables 1, 2 and 3 completed after the delivery of the 1952 crop.

**Table 1.—Report of Mechanical Thinning in Great Western Districts**

| Acres completely machine thinned to eliminate all hand thinning | |
|---|---|
| **Year** | **Acres** |
| 1950 | 294 |
| 1951 | 2,123 |
| 1952 | 10,859 |

**Table 2.—1952 Results of Machine Thinning with Windsor System (Results for 330 Growers and 7,495.66 Acres).**

| | |
|---|---|
| 1952 Average Yield | 15.797 Tons Per Acre |
| Same Farms, Average Last 5 Years (1947-1951) | 13.669 Tons Per Acre |
| Gain in Yield over 5-Year Period | 2.13 Tons Per Acre |
| Average Labor Cost for Summer Work | $13.45 Per Acre |
| **Average of all Great Western Districts** | |
| 1952 Average Yield | 16.51 Tons Per Acre |
| Average 5 Years (1947-1951) | 14.51 Tons Per Acre |
| Gain in Yield over 5-Year Period | 2.00 Tons Per Acre |

**Table 3.—Results on 74 Farms Where There Were Comparative Figures for Hand Work and Windsor System of Machine Thinning.**

| | Windsor Thinned | Hand Worked |
|---|---|---|
| Total Acres of Beets | 879.53 Acres | 1416.58 Acres |
| Average Yield in 1952 | 16.95 Tons Per Acre | 17.03 Tons Per Acre |
| Average Yield, 5 Years | 14.78 Tons Per Acre | 14.78 Tons Per Acre |
| Average Harvested Stand | 77.48 Percent | 69.00 Percent |
| Summer Season Labor Cost | $12.78 Per Acre | $20.66 Per Acre |
| Saving in Labor Cost for Windsor System | $7.88 Per Acre (38%) | |

In 1953 Great Western growers completely mechanically thinned 27,585 acres of sugar beets for which yield comparisons with hand thinned beets are not available at this time.

Growers who have mechanically thinned successfully in the past two years have confidence in the system and do not fear yield losses because of it. These satisfied growers help sell the program to their neighbors, and more growers each year are mechanically thinning their beets. This is resulting in less need for hand labor. Beet workers who have hoed mechanically thinned beets prefer hoeing them to regular hand thinning of beets Growers are producing beets at a lower labor cost per acre.

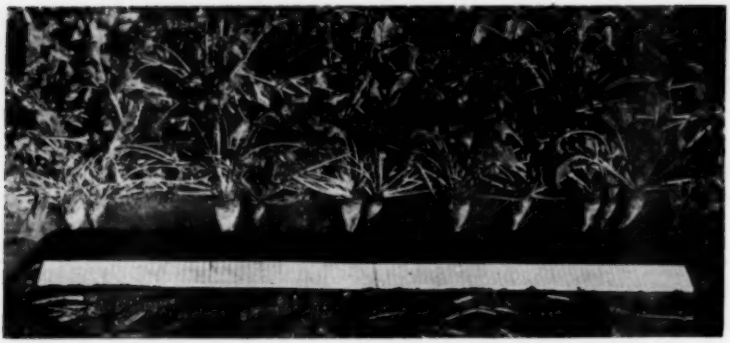

**Figure 3.—Ten feet of row of machine-thinned beets in the ground at harvest time.**

During the past five years, the performance of our recruited field labor has increased steadily. The reason for this increase in worker performance is attributable to at least two things. One is the recruitment of a better class of workers and the elimination of the known "no good" from our shipping lists. The second, and probably most important factor, is the use of the G. W. thinner. An examination of the figures will show that during the years from 1948 to 1950 there was a gradual increase in worker performance. In 1951 and thereafter the use of the machine for complete thinning was inaugurated and expanded, and it is in these years that our worker performance has increased greatly.

Table 4 shows the correlation between G. W. thinner use and increase in acres thinned per worker.

**Table 4.—Acres Mechanically Thinned.**

| Year | Acres Thinned As Aid to Labor | Acres Completely Thinned | Acres Thinned Per Worker |
|---|---|---|---|
| 1948 | 1,180 | 0 | 6.8 |
| 1949 | 6,603 | 0 | 6.7 |
| 1950 | 25,558 | 294 | 7.19 |
| 1951 | 46,190 | 2,123 | 8.71 |
| 1952 | 75,194 | 10,859 | 9.89 |
| 1953 | 52,732 | 27,585 | 11.31 |

During the past three years the recruited labor required to thin the crop has decreased from 14,500 workers in 1951 to 12,000 workers in 1953. This is a reduction of 16 percent. The acreage of beets has remained the same. The savings can be attributed directly to the increase in complete mechanical thinning.

# A Dynamometer for Determination of the Power Requirements of a Sugar Beet Thinner

GEORGE W. FRENCH[1]

When designing any type of machine, a knowledge of the power requirements and the stresses imposed upon the various elements of the machine is necessary if a balanced, economical design is desired.

The device herein described measures the torque applied to the driveshaft of an experimental tractor-mounted power takeoff-driven sugar beet thinner. Since the power input is a function of the torque and the angular velocity of the shaft, the power input may be calculated when the torque and r.p.m. of the drive shaft are known. Experience with sugar beet thinners has demonstrated that any small farm tractor has more than ample power to operate a 4-row or a 6-row sugar beet thinner. The need for designing the machine to fit the power source is not a problem. Data are needed concerning the power input required and the loads imposed on the gears, shafts, chains, or belts so that the correct selection of these component parts can be made.

## Apparatus

The dynamometer herein described was designed specifically for use with the experimental counter-rotating beet thinner (1)[2] (Figure 1). In the tests conducted, only the rear head on each of the two rows was used. Figures 2 and 3 show the drive mechanism and the dynamometer attached thereto. A mathematical analysis of this dynamometer is shown in Figure 4.

**Figure 1. — Experimental tractor-mounted 2-row sugar beet thinner used for dynamometer tests.**

## Test Procedure

This dynamometer was built in 1953 and only limited exploratory tests have been made. These tests demonstrated that the dynamometer functioned as intended and provided information on the torque imposed on the thinner head shafts by three types of commercial thinner heads. The heads tested were: 1. 14-tine weeder head; 2. 14-spoke ⅞-inch cut thinner head, and 3. 10-spoke 2-inch cut thinner head. All of these heads are 19 inches in diameter.

---

[1] Associate Agricultural Engineer, Farm Machinery Section, Agricultural Research Service, U.S. Department of Agriculture, East Lansing, Michigan.

[2] Numbers in parentheses refer to literature cited.

**Figure 2.—Variable speed power transmission mechanism with dynamometer installed. The hydraulic cylinder "A" is connected to the pressure gauge mounted on the tractor to the left of the operator. A second hydraulic hose from the cylinder is connected to the pump used for filling the system with oil. The pressure indicated on the gauge is a linear function of the torque applied to shaft "B," which turns at the same velocity as the thinner heads.**

These exploratory tests also indicated that speed and spacing of cut did not markedly affect the torque on the thinner drive shaft. As would be expected, an increase in the depth of penetration in the soil did increase the torque. All of the tests reported in Table 1 were run at 2-¾ m.p.h. Th variables introduced were spacing of cuts across the row and depths of peneration (Table 1). The area on which these tests were made was settled by a 1-inch rain following working with a disk harrow and a spike tooth harrow. The soil, a Conover Loam, as moderately compact but not as hard as soil sometimes found in sugar beet fields at the time of thinning. Each test run was 39 feet long and replicated 10 times. Maximum and minimum readings over the course of each test were recorded.

## Discussion of Results

The torque measurements obtained are based on a series of tests conducted on a single area. They provide an indication of the magnitude of the torque imposed by different types of thinner heads. Additional tests are contemplated.

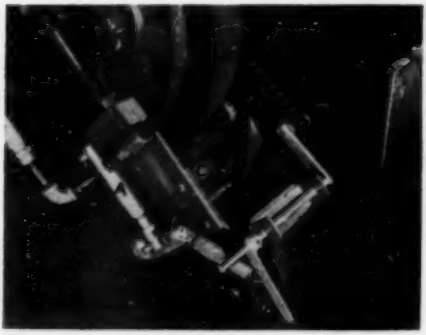

**Figure 3.—Arrangement of component parts of hydraulic dynamometer. Tension in the drive chain exerts force in the idler sprocket shaft which through the idler lever arm, exerts torque on shaft C. The torque in shaft "C" is resisted by hydraulic cylinder A which is connected to the pressure gauge shown in Figure 2.**

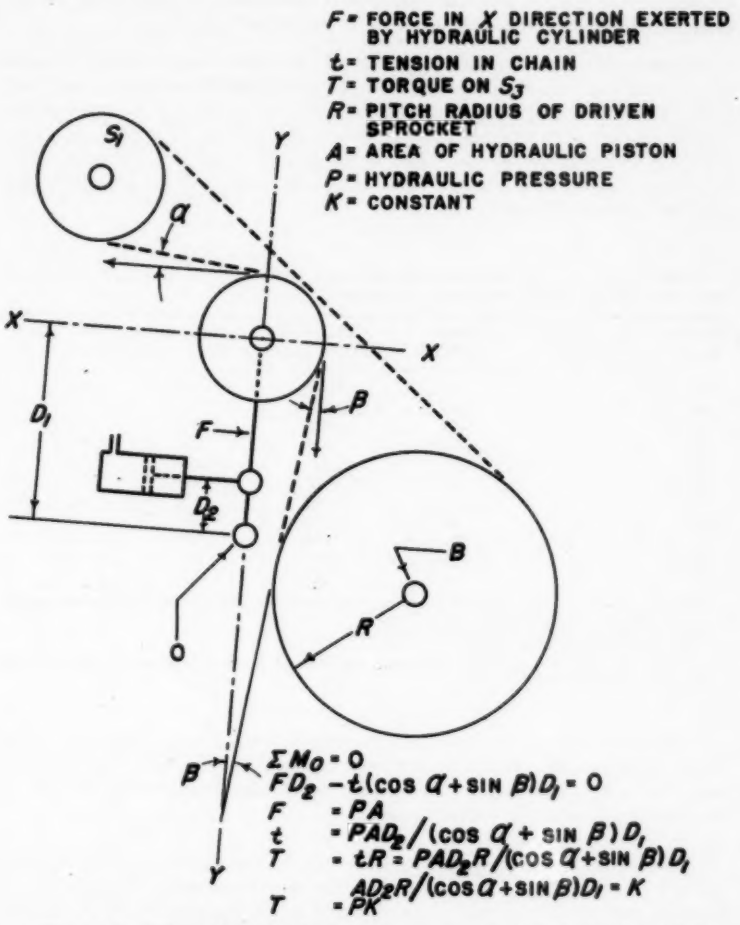


**Figure 4.—Diagram of hydraulic dynamometer and derivation of formula for computing torque applied to driven shaft, $S_3$.**

Total torque in Table 1 indicates the torque on the drive shaft to the thinner required to drive two heads. The figures shown for gauge reading in the fourth column are the maximum pressures observed in any of the ten replications of each test. The fifth column is the average of the maximum readings observed in ten replications.

The thinner used in these tests is a mid-mounted power takeoff-driven machine. The application of this data for design purposes is not necessarily

limited to this type of machine. It may be used when heads similar to the ones tested are operated with any type of sugar beet thinner.

In comparing the effects of spacing of cuts upon torque imposed upon the thinner head shafts, it is seen from Table 1 that the torque is increased with an increase in spacing with thinner heads $H_1$ and $H_2$. The maximum increase occurs with thinner head $H_1$ when the spacing of cuts is increased from 2.4 inches to 4.0 inches. The increase is 26 percent. A reverse tendency is indicated with thinner head $H_2$ as the torque decreases when the spacing is changed from 1.7 inches to 2.8 inches.

**Table 1.—Torque Measurements Obtained in a Series of Tests with Three Types of Sugar Beet Thinner Heads 19 Inches in Diameter.**

| Thinner Head | Cut Spacing (inches) | Depth (inches) | Max. Gauge Reading (p.s.i.) | Aver. Max. Gauge Reading (p.s.i.) | Aver. Total Torque (lb.-in.) |
|---|---|---|---|---|---|
| $H_1$ | 4 | 1⅜ | 1,100 | 919 | 357 |
| $H_1$ | 2.4 | 1⅜ | 900 | 729 | 284 |
| $H_1$ | 4 | ¾ | 850 | 638 | 266 |
| $H_1$ | 2.4 | ¾ | 625 | 566 | 220 |
| $H_2$ | 2.8 | 1⅜ | 1,250 | 1,075 | 417 |
| $H_2$ | 1.7 | 1⅜ | 1,400 | 1,300 | 545 |
| $H_2$ | 2.8 | ¾ | 700 | 568 | 220 |
| $H_2$ | 1.7 | ¾ | 825 | 647 | 251 |
| $H_3$ | 2.8 | 1⅜ | 1,050 | 921 | 359 |
| $H_3$ | 1.7 | 1⅜ | 1,000 | 858 | 323 |
| $H_3$ | 2.8 | ¾ | 325 | 325[1] | 94 |

$H_1$ = 10-spoke thinner head, 2-inch cut.
$H_2$ = 14-spoke thinner head, ⅞-inch cut.
$H_3$ = 14-tine springtine head.
[1] This particular test was only replicated three times and the maximum gauge reading observed in each case was 325 p.s.i.

The most important variations in torque result from changes in depth of soil penetration. The highest torque reading was obtained with thinner head $H_2$ at 1⅜ inch depth. When the depth was decreased to ¾ inch, a 50 percent reduction in torque occurred.

The actual power input is quite small in comparison to the capacity of a one-plow tractor. The maximum power input was recorded with thinner head $H_2$ with a 1.7-inch spacing of cuts and a soil penetration of 1⅜ inches. The thinner heads rotated at the rate of 123 r.p.m. The average maximum torque was 545 lb.-in. and the calculated power input was 1.06 horsepower. This figure for power input involves only the power required to rotate the thinner heads. Obviously, a certain amount of power is required to overcome resistance to forward movement along the row. Tests could be revised to measure this component of the total power input but it appears that such information is not particularly essential for design purposes.

**ACKNOWLEDGMENTS**

The writer wishes to acknowledge the assistance rendered in the construction of this device and the preparation of the manuscript by George R. Stafford, Engineering Aid on this project, and Ernest H. Kidder, Carl W. Hall, and Walter M. Carleton, of the Agricultural Engineering Department, Michigan State College.

## Literature Cited

(1) FRENCH, GEORGE W.
1952. A report on tests of mechanical weeding and thinning equipment in Michigan. Proceedings Amer. Soc. Sugar Beet Tech.

The study herein reported was conducted as a cooperative project between the Agricultural Engineering Department of Michigan State College and the Farm Machinery Section, Agricultural Research Service, U. S. Department of Agriculture.

# Five Years' Mechanical Harvesting Experience with Completely Machine Thinned Beets

A. M. WATSON[1]

The mechanical harvesting of sugar beets which are thinned mechanically results in problems which we do not have with hand-thinned beets. This is due to the uneven spacing of beets in the row, and uneven growth above the ground. Finders on mechanical harvesters are not flexible enough to catch the small beets close to the large ones.

Our experience starts with a 35-acre field planted in 1949 for the purpose of developing the thinner. The final stand varied from exceptionally good machine-thinned beets to variations of the original stand. This was due to the trying out of various ideas and machines of all individuals interested in the development of the thinning machine. When we harvested these beets it was necessary to top a large percent of them after the harvester had delivered the beets into the truck

In 1950 we harvested 294 acres of mechanically thinned beets using four International harvesters. One of these harvesters was equipped with a Parma beater unit. We used four operators to operate the machines, eight men on the picking table, three truck drivers delivering beets to the factory, and two additional men trimming beets which had been delivered into the trucks. This gave us a total of seventeen men on the crew. The Parma beater unit, while a little difficult to use, showed considerable promise in cleaning up the beets which were poorly topped.

In 1951 we harvested 250 acres with these four International harvesters. We had two of them equipped with Parma beater units and one equipped with an experimental International harvester beater unit. We were able this year, to get by with one man trimming beets in the truck. We had only one harvester without a beater unit. Nineteen hundred and fifty-one being an exceptionally wet year in our district, we were unable to harvest the acreage in reasonable time so we secured the help of a neighbor who owned a Marbeet. This machine did an excellent job for us.

In 1952 we purchased a Marbeet harvester. We used two of our Internationals equipped with International beater units and another International equipped with a Parma beater unit. We harvested 241 acres without the use of the man trimming beets in the trucks. We found the beater units rather expensive to keep in operation; and it was decided that, for our conditions of exceptionally heavy soil, and all mechanically thinned beets, that the Marbeet was doing a much better job for us both in topping small beets and recovery of beets which would normally be lost by the International harvesters. We have found that the Marbeet is able to harvest considerably more acreage per unit of time than the International.

In 1953 we harvested 244 acres with two Marbeet harvesters and one International in 19 days, and reduced our manpower to 13 men as com-

[1] Manager, The Great Western Sugar Company, Windsor, Colorado.

pared with 17 in 1950. We found that during the harvest we were delivering beets which were free of trash or tops and comparable to beets delivered by growers with hand-thinned beets. We find on the average year that our return dirt in the trucks from the Marbeet harvester will be from 300 to 500 pounds less than that delivered by the International. We also have better recovery of beet tops. In weighing dried tops we find that we will get one-third more by weight from the harvest with Marbeet. This is due to the tops being thrown free from the wheels which normally pack down the tops to where it is hard to recover them. We find that we are better able to control our topping, and have fewer large crowns left with the tops, which are quite dangerous when being fed to small cattle.

# Harvesting Equipment[1]

GEORGE W. NIXON[2]

The fall mechanization of the sugar beet crop has come a long way since its inception in 1943. In American Crystal territory in 1953, utilizing 1,383 harvesting machines, 94.3 percent of the total acreage was machine harvested.

Since the advent of complete mechanization of the crop from spring work through the harvest many serious problems have developed, caused chiefly by trash and clods and small improperly topped beets from overpopulated stands because of improper machine thinnning in the spring. The seriousness of these problems is reflected in the factory delays and losses of tonnage and sugar in storage piles.

Storage pile aeration has given commendable results; however, the excess concentrations of dirt and tops often cause heating and the necessity of removing portions of storage piles prior to the time that they are ordinarily removed.

Because of these varied problems it is necessary to carry on an intensive educational campaign with the grower, starting early in the crop year, to make definite plans for mechanizing his beet crop. These recommendations to the grower are as follows:

1. Proper fertilization and good seed bed preparation.

2. Proper planting with a good precision planter, speed of planter never to exceed 2½ miles per hour.

3. Checking row widths carefully and planting as recommended in the particular area.

4. Down-the-row machine thinning done on a timely basis, taking a generous number of stand counts, and never being too conservative or using a smaller knife than the count indicates. Using every precaution to eliminate bunches and overpopulations.

5. Eradication of summer weed growth either mechanically or by the use of the various chemical sprays.

6. Conditioning of the soil in dry years by light irrigation prior to harvest.

The quality of work with the present available harvester can be directly attributed to the operator. Proper adjustment of the machine as conditions in the field vary, proper depth, speed not to exceed 2 to 2½ miles per hour—these factors are very important. A pertinent point is that speed in excess of this will cause the average operator to dodge off the row.

In the Red River Valley of Minnesota, fieldmen made a total of 103 strip tests following harvest operations (each test consisting of four rows 100 feet long), for the purpose of determining the average tonage lost in

---

[1] This report includes information on lifting, screening and topping with emphasis on trash removal and other innovations for improvement of harvesters.

[2] Agricultural Superintendent, American Crystal Sugar Company, Rocky Ford, Colorado.

the harvesting operation. On an average, a loss of 1.25 tons per acre was found, with a high of 4.18 tons per acre and a low of .07 tons per acre. After a complete study of these tests, it was found that the low or high losses cannot be attributed to any one harvester, which means the good or poor performance of machines is dependent entirely upon the operator.

We can therefore conclude that the principle of the present harvesters is fairly well established and the problem appears to be more in perfecting existing models rather than developing some new approach. Manufacturers, it would appear, should think more in terms of quality of work, by more efficient elimination of dirt and trash and conservation of the tops, rather than large production at the expense of good quality work.

In American Crystal territory the California area harvests practically all beets with the Marbeet 2-Row Harvester. The only improvement which has been added to the machine the past year is the use of the longer spike which is standard now for the Marbeet Midget. These spikes are approximately ½ inch longer than the spikes which originally came out on the two-row machine. The longer spikes have resulted in a definite improvement in the ability of the machine to pick up beets. Because of the firm spiking of the beets to the wheel a cleaner job of topping is done.

A local farmer in the Oxnard area has developed a 4-Row Marbeet Harvester which did a very acceptable job and harvested a large tonnage of beets.

In the inter-mountain area, the International Harvester is most widely used. It is considered by the grower to be a dependable machine in that he can harvest his crop of beets regardless of rain, snow or dry and hard soil. The objections to this machine are many, as it is slow under normal conditions, requiring the use of two or three workers on the picking table. However, it does a fair topping job but generally leaves the tops in poor condition.

Several improvements for the International machine were released this year, chiefly the puller wheel attachment which consists of two 24-inch diameter steel alloy cast wheels. These wheels are mounted in such a way that they have a converging action which causes the beets to pop out of the ground. These wheels are furnished as an attachment only, and replace the puller standards, blades, and roller coulter assemblies. Their purpose is the elimination of clods, resulting in a one man operation for the machine. This attachment worked fairly well after many adjustments by factory mechanics under dry conditions, but failed completely under wet conditions and was removed by the growers in most cases.

The Marbeet Midget was introduced to the area in 1952 and was well received by growers. This machine operates under normal or extremely dry conditions very satisfactorily. However, under extremely muddy conditions, such as were experienced in the Texas area following 10½ inches of rain, this machine did not perform satisfactorily.

The Marbeet Midget does a good quality job of topping and reduces tare in comparison to other machines as shown by Table 1 on data compiled in the Rocky Ford district.

**Table 1.—Relation of Tare on All Machines Compared with Mabeet at 100 Percent.**

| Type of Machine | No. of Machines | Tons Harvested | Tons Harvested | % Tare | Percentage |
|---|---|---|---|---|---|
| International | 33 | 1,494 | 21,686 | 4.70 | +27.02% |
| Marbeet | 11 | 686 | 11,036 | 3.43 | |
| John Deere 2-Row | 2 | 137 | 1,590 | 5.15 | +33.59% |

In the eastern territory at Mason City, Iowa, the Scott-Urschel machine is used chiefly. The Scott-Urschel's principle of handling the beets by their tops eliminates large quantities of dirt which has to pass through other types of machines. The Scott-Urschel has introduced a roto-beater gadget which, mounted in the elevator, does a good job of removing loose leaves, streamers and clods.

Walter Quandt, a grower in the Chaska, Minnesota, area has developed a 4-row harvester mounted on a No. 212 Caterpillar road patrol. Mr. Quandt through good farming practices has been able to go to 12-row planting, thus making a 4-row harvester feasible. The Quandt machine uses John Deere spike lifters and has a five-roll Molnau screen mounted to receive the beets from the potato chain. Mounted above the screen is an Olson roto-beater flair, operating against the flow of beets.

Zuckerman topper units were brought in from California and growers of the area built one 6-row topping unit, one 4-row unit and five 3-row units. The 3-row and 6-row units were used with the 3-row harvesters. The Zuckerman unit has roller finders with a knife under each roller. This was a very fine topping unit for the area when the operator did not exceed a speed of two miles per hour. The tops are removed by a side delivery rake and a very clean field is left.

Splendid results were secured by welding a rim of plow point steel on the rim of the John Deere lifter wheels. Quantities of clods being lifted were reduced by 75 percent. This is an exceptional improvement for the area under very dry soil conditions.

**Table 2.—Progress of Machine Harvesting, 1943-1953, in American Crystal Sugar Company Areas.**

| Year | Number Machines Harvesting | No. Acres Machine-Harvested | Acres Per Machine | No. Tons Machine-Harvested | Avg. Tons Per Machine | Percent of Total Acreage Machine |
|---|---|---|---|---|---|---|
| 1953 | 1,383 | 122,569.8 | 88.6 | 1,484,576 | 1,073.4 | 94.3 |
| 1952 | 1,266 | 108,560 | 85.7 | 1,275,072 | 1,007.1 | 88.6 |
| 1951 | 1,184 | 100,663 | 85.0 | 1,326,722 | 1,121 | 78.15 |
| 1950 | 943 | 83,069 | 87.6 | 1,039,938 | 1,097 | 56.36 |
| 1949 | 671 | 48,769 | 72.7 | 676,757 | 1,009 | 46.25 |
| 1948 | 565 | 46,116 | 81.6 | 604,706 | 1,070 | 46.40 |
| 1947 | 305 | 22,913 | 74.2 | 371,369 | 1,202 | 27.60 |
| 1946 | 172 | 16,246 | 94.4 | 270,758 | 1,574 | 20.61 |
| 1945 | 82 | 11,126 | 135.7 | 167,698 | 2,045 | 16.22 |
| 1944 | 36 | 3,711 | 103.1 | 61,226 | 1,701 | 7.64 |
| 1943 | 9 | 1,908 | 212.0 | 30,000 | 3,333 | 4.01 |

The International Harvester is used to some extent in the area. Growers are using a small Molnau trash-removing screen mounted at the top of the elevator, consisting of two bed rolls and two raised rolls. This installation removes a tremendous amount of trash.

The northern Minnesota area does not conserve the tops for feed to any extent and efforts of growers of that area to eliminate trash are concentrated in the field by the use of the roto-beater ahead of the harvester, which takes care of the problem fairly well. Table 2 shows progress of mechanical harvesting in American Crystal territory in the past eleven years.

# Influence of Machine Harvest on Receiving Facilities

AUSTIN ARMER[1]

Beet-receiving facilities embrace all of the mechanisms needed to receive sugar beets from field trucks, weigh the beets, remove and weigh foreign matter, and deliver the clean beets to factory bins or piles. The devices currently in use are, for the most part, adaptations of much earlier equipment, originally designed for receiving handharvested beets delivered by horse-drawn wagons. To be sure, the improvements to accommodate modern methods or harvesting and delivering sugar beets have kept pace fairly well. Nevertheless, there is some reason to believe that a fresh approach to the problem as it now exists would yield a receiving station design far superior to the present modification of earlier designs.

## Peculiarities of Machine-Harvested Beets

It would be well if this heading included also "machine-thinned beets." The present trend toward mechanizing all cultural operations from land preparation to the delivery of harvested beets has brought about a condition of the beets as delivered which merits close examination. The tabulation to follow will list the principal physical characteristics of beets as delivered from fields where all cultural operations have been fully mechanized. Such beets are:

1. Brittle—easily fractured by impact.
2. Odd-shaped—from inaccurate topping or partial breakage.
3. Slippery—as a result of surface bruising and adhering undried mud.
4. Trashy—frequently mingled with weed roots, beet leaves, and soil particles from dust to large clods.
5. Widely varying in size—as the combined result of machine thinning and the ability of harvesting machies to recover beets of all sizes.

A receiving station capable of meeting this array of conditions must differ from existing installations in all of the respects in which the above characteristics differ from those of hand-harvested beets. These differences may be tabulated in a manner parallel to the foregoing list.

1. Fracturing of beets must be avoided by dropping them a minimum distance, and onto a sloping surface or other means for minimizing damage.
2. The irregular shape of mechanically produced beets precludes any handling or cleaning devices which depend on the uniform shape or size of beets.
3. The slippery surface characteristic of machine-harvested beets reduces the slope of belt conveyors which will operate satisfactorily.

---

[1] Agricultural Engineer, Spreckels Sugar Company.

4. The trashy nature of machine-harvested beets as presently encountered calls for marked improvement in cleaning devices.

5. The small size of many of the beets now received is also reason for revising present cleaning methods.

The first requirement is being met by reducing the distance through which beets must be dropped into the receiving hopper from the field truck, and in delivering beets to bins and piles. The most recent designs of receiving hoppers present a sloping surface on which the beets fall so that the impact is less violent than would be the case of beets falling on to a horizontal surface. There is, however, still room for improvement, because broken beets and small beet fragments lead to substantial losses either through diffusion in the flumes or loss of fragments through the screens.

The irregular shape of beets as now received results not only from topping irregularities and breakage, but also from the extended harvesting season which causes the crown of beets to grow from a roughly hemispherical shape to a steep conical shape ("pineapple crowns"). The tendency of these odd-shaped beets to roll backwards on conveyor belts conspires with their tendency to slide backwards because of their slippery surface. The result is that many uncleated belts which conveyed the old hand-topped beets with complete satisfaction have become almost useless for beets as now received. A smooth belt with a slope of 23 degrees has been considered perfectly satisfactory in the past and slopes up to 30 degrees have been used, although cleats were generally applied after the slope exceeded 23 degrees.

A contrasting situation was encountered last year with a 48-inch conveyor belt with a 13 degree slope which failed to transport machine-harvested beets after cleaning on a conventional Rienks screen. It was necessary to apply cleats of fabric-reinforced rubber one inch high in order to prevent back-slip.

The shortcomings of existing cleaning devices probably represent the most unsatisfactory aspect of existing installations. There is need for serious study and perhaps radical redesigning of cleaning devices so that they will sharply distinguish between beets of all sizes and foreign matter in all of the varieties now encountered. Then, after the discriminating ability has been achieved, the physical behavior of the screen toward the beets should be considerably less violent than now encountered, so that damage to beets will be reduced. It is, of course, useless to strive toward a screen which perfectly achieves these characteristics, so that certain tolerances should be established in relation to:

A. Percent by weight of foreign matter remaining in clean beets.

B. Maximum diameter of beets or beet pieces which may pass through the screen.

### Trends Which Affect Receiving Station Design

The discussion so far has been concerned with the physical nature of machine-harvested beets. But concurrent with mechanical harvesting, there

have been other changes affecting the design of receiving stations. Trucks are longer and carry heavier loads.

The large capital investment in harvesting machines and trucks calls for a minimum of unloading time. There appears to be a growing acceptance of large transport trucks as a partial replacement of railroad cars; this means that rail dumps must accommodate both railroad cars and transport trucks.

Finally, the transient nature of beet growing in certain areas emphasizes the need for greater portability of receiving stations.

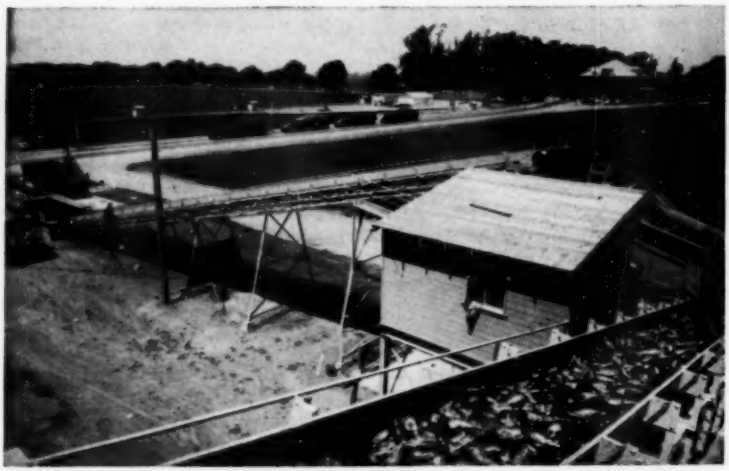

**Figure 1.—Both conveyor belts on this receiving station (built in 1953) have a slope of 13 degrees, yet screened, machine-harvested beets could not be conveyed on the second belt (foreground) until it was provided with cleats.**

## Summary and Conclusions

This discussion has been somewhat obviously lacking in specific recommendations. It has been, rather, a broad definition of the problem of beet receiving and a demonstration of the shortcomings of the existing equipment. The discussion may be considered as basically a recommendation for a further study on the widely differing physical characteristics of sugar beets as now received, leading up to a design of a receiving station to be made without dependence on preceding designs, except as these may offer valuable design guidance. The need for research on the design of cleaning screens is emphasized, and a realization of all the cultural and custom trends in beet growing and harvesting is urged.

# Relationship of Screening to Beet Population

L. J. Holmes and Curzon Kay[1]

Early in the spring of 1953 we became quite concerned with the high beet population which was observed in our fields at Clarksburg. In making stand counts in connection with mechanical thinning we noted much to our amazement that many of the hand-thinned fields had higher populations than mechanically thinned stands. We have also noted the increase of doubles, triples and clumps in these fields over past years.

As we have discussed the reasons for and some of the agronomic results of these high populations in a paper presented to the agronomy section of this society we will confine ourselves in this paper strictly to the problems caused by these high populations at the receiving stations and the related harvest problem.

At Clarksburg the receiving station consists of a 7-foot Molnau screen preceding a standard 84-inch Rienks screen. All of the beets delivered to Clarksburg are received over this station. The average tare for the first 30 days of harvest in 1952 over this installation was 4.0 percent. The average tare for the first 30 days of 1953 over this same installation was 6.6 percent. This is a comparison of beets received from the same growers in the same area, with the same harvest equipment. Ninety-eight percent of the beets received both years was from mechanical harvesters.

We were greatly concerned at Clarksburg by this increase of 2.6 percent in our tare over the previous years and we immediately began an investigation to determine the reasons.

On careful study of the situation we found that the increased tare was due to the increased number of small, poorly topped beets which were being caught in the sample bucket. In addition we noted a large number of unmarketbale beets which were being screened out through the Molnau screen.

As a matter of interest we decided to take the screenings from average six-ton load of beets and determine whether there was any correlation between field population and the number and weight of unmarketable beets which were being received. Table 1, and photographs 1, 2, 3, and 4 of Figure 1, show the results of this study. It is interesting to note the high positive correlation between the field population and total weight and number of unmarketable beets in the screenings.

The problem of the poorly topped small beets in the sample is of course related directly to the harvest problem. The majority of the harvesters in our territory are the Marbeet Midgets and Marbeet Standard two-row. With these machines, as well as with any beet harvester which we have observed, when beets are left in clumps the largest beets or the beet with the highest crown gets topped and the rest of them barely get a

[1] Manager, and Agricultural Superintendent respectively, American Crystal Sugar Company, Clarksburg, California.

haircut. Photograph 5 of Figure 1 shows graphically what we are talking about. Of the twelve or more beets which are to be harvested only four are going to receive an acceptable topping job.

In addition, there is the added harvest problem of recovery. With the Marbeet Midget particularly, and we think this applies to almost all one-row harvesters, if two beets grow side by side in the row there is a very good chance that only one of them will be harvested. It is practically impossible to stay exactly in the center of the row at all times, and when the harvester comes to these beets if it is off to one side or the other to any extent one of these two beets is going to fall to the side and not be picked up. Photograph 6 of Figure 1 shows an example of two such beets.

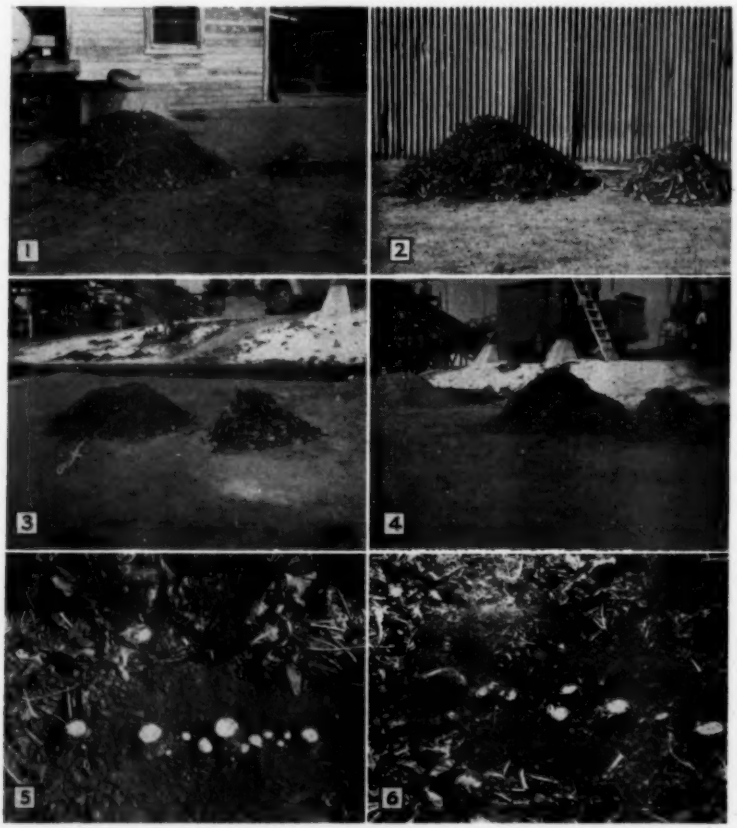


**Figure 1.—Photograph 1—Hand-thinned, 110 beet stand; 2—hand-thinned, 158-beet stand; 3—cross-blocked, 165-feet stand; 4—Dixie, 173-beet stand; 5 and 6—field stands with tops removed (see text).**

It is our conclusion therefore that we in the beet industry in striving to push spring mechanization have caused our growers to become too lax in their field supervision of hand labor. We have also allowed them to leave too many poorly thinned beets in the fields, and many growers using mechanical thinners have left too high a population. We feel that more harm is being done by leaving too many beets than would be done by leaving too few. While this increased population may or may not affect the tonnage it has without a doubt lowered the quality of the harvesting job, and has increased the amount of trash which must be handled at the receiving station.

As final proof of this we would like to cite the comparison of total screenings from beets received at Clarksburg in 1952 and 1953. Prior to the first rain at Clarksburg in 1952 we had received 183,964 tons of beets with 11,245 tons of screenings. In 1953 from 183,554 tons of beets, again prior to any rains, we had received 12,479 tons of screenings. It is our opinion that this increase of 1,234 tons of additional screenings in 1953 is due to the increased number of unmarketable beets caused by leaving too high a population in the fields at thinning time.

**Table 1.—Comparison of the Amounts of Unmarketable Beets in the Screenings from Average 6-ton Loads at Claksburg—September 30, 1953.**

| | Population Per 100' of Row at Harvest Time | Total Wt. of Screening | Wt. of Small Beets in Screenings | Number of Small Beets in Screenings |
|---|---|---|---|---|
| | | lbs. | lbs. | |
| Hand Thinning | 110 | 260 | 3.31 | 55 |
| Hand Thinning | 158 | 560 | 93.13 | 940 |
| Cross-Blocked | 165 | 570 | 100.57 | 977 |
| Dixie Thinner | 173 | 1,200 | 145.76 | 1,293 |

# Comparative Efficiency of Rubber and Steel Rienks Screens

CHARLES R. JOHNSON[1]

The objective of this study was to obtain preliminary information as to the relative screening ability of rubber and steel Rienks-type screens.

The beet receiving station at Lambert in the Fort Morgan, Colorado, district, and the factory station at Eaton, Colorado, were selected as suitable for this test.

The Lambert station has a 36-inch 1950 Silver piler with a rubber Rienks screen, and also a 36-inch 1946 Silver beet dump with a steel Rienks screen. The two screens are of identical size, being 60 inches wide, with six forward and two reverse rolls. Both screens were set to run at 144 r.p.m. No effort was made to study comparisons on individual trucks, and only figures for the entire season were considered. After weighing in over the scale, the driver went either to the piler or dump, depending usually upon which waiting line was the shorter. Tare tickets at the piler and dump were marked for later separation, and loads over the dump and piler were shown in separate columns on the receiving station record.

The same procedure as outlined above was followed at the Eaton factory station. At this station, the 1950 36-inch Silver piler which was used to pile beets outside of the regular storage area has a rubber Rienks screen and is 60 inches in width with six forward and two reverse rolls. This screen was revolving at 140 r.p.m. The regular receiving system for the Eaton factory has two steel Rienks screens, each having eight forward and one reverse roll. The reverse roll, however, is solid on each screen. The hubs on the steel kicker wheels have a 6-inch diameter, compared to a 4½-inch diameter of the hub of the rubber screen on the Silver piler. From observation, the smaller hub on the kicker wheel allows more dirt and clods to go through the screen. The steel screens were both revolving at 94 r.p.m., which prevented exact comparison of the equipment.

At the Lambert station, the 1,926 loads taken over the rubber screen had an average tare of 11.93 percent, while the same growers hauled 1,865 loads over the steel screen which had an average tare of 6.81 percent. Of the 44 growers who hauled loads over both screens, 43 received a higher tare over the rubber screen. A statistical analysis of the number of loads, gross weight, empty weight, first net, percent tare and final net over both screens, points to the fact that 172 pounds per load were credited to the grower in excess for beets hauled over the steel screen as compared to loads over the rubber screen. Statistically, this was significant at the 1 percent level. In other words, the tare over the steel screen should have been about 1.5 percent greater, or 8.31 percent instead of 6.81 percent, in order to equalize dirt return and final net of beets hauled over both screens.

At Eaton 3,355 loads over the rubber screen averaged 9.33 percent tare, while 3,326 loads over the steel screen averaged 7.42 percent tare, a differ-

---

[1] Assistant to southern district manager of the Great Western Sugar Company.

ence of 1.91 percent. Of 79 growers who delivered beets over both types of screens, 66 received higher tares from the rubber screen but had more dirt returned to the truck when they delivered over the steel screen. A comparison of final net returns over both screens points to the fact that 45 pounds per load in excess were credited to loads over the steel screen as compared to loads over the rubber screen. The tare over the steel screen should have been approximately .5 percent greater to equalize the net return over each screen.

The screen speed on the Silver piler with the rubber screen at the Eaton factory was reduced from 140 r.p.m. to 117 r.p.m. on October 21, 1953. Forty-four growers delivered to the piler before and after this change in screen speed, and 855 tares taken at a screen speed of 140 r.p.m. averaged 8.7 percent, while 500 tares from the same growers taken at a screen speed of 117 r.p.m. averaged 10.7 percent. This difference in tare could have been influenced by a variation in fields and soil moisture conditions, although no precipitation fell during this period.

The rubber screen has a surface opening for dirt to fall through of 43.45 square inches per 144 square inches, while the steel screen has a total opening of 52.87 square inches per 144 square inches of surface. This means that a steel screen has 20 percent more surface opening for dirt and clods to fall through than the rubber screen. From this it might be deducted that if rubber Rienks rolls are devised to allow greater opening area, this difference in percent tare and dirt return to the grower over both screens might be more nearly equalized.

At 117 r.p.m. the kicker wheel 12 inches in diameter, as used on Rienks screens in Great Western Sugar Company areas, will have a peripheral speed of 367 feet per minute. This speed is comparable to that of a 14½-inch diameter kicker wheel used on Rienks screens in some areas and revolving at 100 r.p.m., with a peripheral speed of 373 feet per minute.

A vertical drape of rubber belting was installed over the rubber screen just back of the reverse rolls on the 1953 Silver piler at Fort Lupton. This appeared to catch beets and drop them back on the screen instead of bouncing into the boom hopper, thus resulting in more screening. A vertical drape, based on our observations, is better than a "blanket-type" belting lying in contact with the screen, as it does not force as many small beets through the screen.

Conclusions from this study are as follows:

1. Tares are higher on loads over the rubber Rienks screen than over the steel screen, while more dirt is returned to the truck by the steel Rienks screen.

2. A balance of net returns over both screens indicates that the percent tare taken over the steel screen was, in these tests, lower than it should have been to compensate for the weight of screened dirt returned.

3. A revision of the rubber Rienks rolls is needed to allow more opening for returning dirt to the truck and lowering the tare.

4. The rubber Rienks screen has shown to advantage in areas where the soil contains rocks which stop a steel screen, while a rubber screen will continue to operate. A rubber screen will also operate under wet, heavy soil conditions which will interfere with and plug a steel screen.

5. The rubber screen is less liable to break beets and puts them into the pile in better condition for storage; however, the pile will contain more dirt.

# End Dump Arrangements on Old and New Receiving Equipment

R. W. Brandt[1]

Approximately 50 percent of American Crystal Sugar Company's present beet receiving equipment in the Red River Valley will handle the unloading of end dump trucks. We have eight different types of loaders with end, or combination end and side dumping facilities. These eight types include the 30-inch Ogden Piler, the 30-inch Lynch Loader, the 30-inch Silver Roberts Loader, the 30-inch Silver Loader, the 36-inch Silver Engineering Works Loader, the 36-inch Silver Engineering Piler, the 36-inch Silver Engineering end dump Loader, and the 38-inch Ogden Loader.

In 1947 we coverted our first side beet loader to a combination end and side loader and, in 1949, one more was converted. One end and one combination end and side loader were purchased in 1951 and one end and one combination end and side loader were purchased in 1952. In 1953, three end dump loaders and one end dump piler were purchased and five more conversions were made.

We find that this changeover in the type of our receiving equipment has been beneficial to both our growers and ourselves. A high percentage of farmers in this area has been purchasing hydraulic end dump equipment and new grain boxes for their trucks; and these changes have made it possible for them to use the same box for beets which they use for grain. Machine harvesting has speeded up deliveries of beets, and the timesaving factor of unloading has been valuable to them also. These changes to end dumping have made it possible for us to reduce our station crews, have increased the efficiency of our loaders and have greatly reduced the amount of work for the main station operator. Loaders which have been converted to straight end dumping have made it possible for us to remove troublesome mechanisms and, consequently, have reduced maintenance on these loaders.

Possibly the most important factor of this end arrangement of dumping is its ability to handle muddy beets faster and more efficiently than with the old fashioned side dumping. The flow of beets from truck box to hopper can be controlled much better hydraulically than with a friction-type cable hoist and, in handling muddy beets, this ability almost eliminates the cause of beets lodging in the hopper. Muddy beets pass out of this new, completely open pit a great deal easier than through the funnel-type side hopper.

In converting a 30-inch Ogden Piler for straight end dumping, it was necessary to remove the "A" frame used for hoisting loads, and also the wooden platform. After this portion of the loader was eliminated, a cement retaining wall was built parallel and adjacent to the long open hopper. After placing a broad dirt fill against the cement-retaining wall and laying a cement slab on top of the dirt fill, beet loads could be unloaded by the

[1] Agricultural Superintendent, American Crystal Sugar Company, East Grand Forks, Minnesota.

truck operator driving over the fill, making a right angle turn, and then backing truck at right angles to the long open hopper.

One of our 30-inch Lynch Loaders was changed to combination end and side dumping by placing a retaining wall and dirt fill directly behind the side dumping pit. This arrangement allowed trucks to unload from an end position of the belt as well as by the conventional side method.

Another 30-inch Lynch was converted to straight end dumping after removing platform, hoist clutch, "A" frame, and side hopper. After this portion was removed, a square concrete pit and hopper were built around the ground end of main conveyor. This square concrete pit had to be built a little higher than the usual concrete Lynch dirt pit, as the top portion of this new concrete pit was used to support the sides of the newly fabricated sheet iron open beet pit. A dirt fill was placed in front of the cement pit and hopper to enable trucks to back up to the loader and unload from an end position of the belt. This loader proved to be very successful and growers were well pleased with the change.

Two 30-inch Lynch Loaders, two 30-inch Silver Roberts Loaders, a 30-inch and 36-inch Silver Engineering Works Loader were converted to combination side and end dumps. This was accomplished by removing a six-foot section of platform directly over the belt on each machine, and installing two runways for truck wheels to pass across the removed section (Figure 1). The overhead wooden "A" frame was also removed from the Lynch Loaders and a single steel side "A" frame was installed for lifting loads that had to be side dumped. The runway cleaning device was constructed by hinging safety tread steel plates to runways. These cleaning plates are manually operated on two of our conversions and hydraulically operated on the other conversion (Figure 2). We fabricated a sheet iron pit directly under the platform opening and installed one additional roller under the belt to support extra weight of beets on the belt. These conversions worked out very nicely and speeded the handling of beets at these six points.

In the Red River Valley, we have made purchases of two 38-inch Ogden Combination end and side loaders, and two 38-inch Ogden all end dump loaders; however, plans are to convert the two combinations to straight end dumping for 1954. This will be done by removing the platform, the "A" frame, and hoisting mechanism. After this portion is removed, we plan to install a concrete dirt-retaining wall along the hopper and make a dirt fill and lay a concrete slab on top of the fill. This will allow trucks to back in at right angles with the long open hopper. Under the old arrangement, it was necessary to back a truck through a steel "A" frame and it was sometimes difficult to maneuver trucks into the unloading position. The removal of these obstacles will also eliminate the danger of an operator being pinned between the truck and steel "A" frame. It will also reduce maintenance and, in general, will be a much less confusing way of receiving beets.

Two years ago, it was necessary for us to make plans to purchase additional stationary loaders. Our experience with end dumping on changed-over loaders convinced us to encourage some manufacturer to design and

Figure 1

Figure 2

construct an all end dump loader without the usual side dumping mechanisms. He contacted several manufacturers and asked them to design such a loader. We encouraged them to embody some of the proven end dumping principles of our previous conversions and we also made further suggestions regarding its design. They agreed to design and blue print such a machine and, after the blue prints were presented to us for consideration, we were satisfied to the point of purchasing three of these machines. They are right angle loaders, with 6-foot rubber reinks cleaning screens and 36-inch conveyor belts. These loaders are designed to enable beet loads to drive directly over the end of the conveyor belt, by passing over two wheel ramps constructed at right angles across the belt (Figure 3). The wheel ramps mechanically clean themselves by being driven or raised with a separate electric motor after each load has finished unloading and removed itself from the ramps (Figure 4). A good feature with this type of unloading is that it eliminates the necessity of backing a truck load of beets, which is sometimes difficult and dangerous to do. This time saving and less confusing way of unloading beets is unique and serves the purpose at stations that require the handling of 1,500 to 1,600 tons per day. These loaders, and particularly this principle of receiving beets, worked out exceptionally well and we have only minor changes that we would recommend to the manufacturer to make on future models of this loader.

This year our company purchased a 36-inch Silver Piler, plus a separate Silver end dump ramp mechanism which operates adjacent to, but separately from, the piler. This turtle-appearing unit has the ability of accepting an end-dumped load of beets and delivering it to the piler hopper. Trucks

Figure 3

Figure 4

pass up and over this affair and stop just as the end of the truck box passes center position of the ramp unit. Hydraulic mechanism pulls a floor section of the ramp back, and in an up position, to form one side of an open hopper. Hydraulic power also raises a smaller section of the ramp floor on the truck side of the hopper to form the second side ofthe hopper. Outside of controlling the movement of the unit and supplying power for the main beet conveyor, practically all other mechanisms are hydraulically controlled on this end dump ramp unit. This is the first end dump unit of this type that Silver Engineer has built. It worked remarkably well for the first year and we have only a few minor suggested changes to recommend to the manufacturer on future models.

# Beet Receiving Equipment

GLEN W. YEAGER[1]

Many changes have been made in beet receiving equipment during the past two decades. The original highline beet dumps which were so familiar throughout beet growing territories have all been dismantled and replaced with modern beet receiving equipment. The old stationary grizzly bar screens on highline dumps have given way to modern screening machinery. Manually operated highline dumps have been replaced with the new modern beet dumps operated with electric power.

The old familiar scene of many wagons and trucks lined up beside the beet pile and men shoveling the beets from the wagons and trucks into the pile has been replaced with beet piling equipment capable of handling the heavy daily beet deliveries. The potato chain screens have been replaced by Rienks screens and other modern screening equipment. All of these changes have improved and expedited beet receiving.

The innovation of mechanical beet harvesters increased the need for beet receiving equipment which would handle heavier daily beet deliveries and do a better job of removing foreign material from these deliveries. A change from the original closed type steel Rienks wheels in the screens to open type steel wheels, and more recently to rubber wheels, resulted from the need for improved screening devices.

Many of the original single unit beet dumps and beet pilers have already been replaced by the double type beet dumps and pilers to meet the need created by faster harvesting. Late improvements on beet pilers include large hoppers, longer stacker booms, improved moving clutches with dual track drive, improved tare samplers and equipment to remove excess trash and dirt, combined with heavier construction throughout. These advancements have helped keep pace with the many changes taking place in the harvesting and receiving of sugar beets.

Modern beet receiving equipment has made it possible to combine two or more small receiving stations of the old fashioned equipment into one large receiving station where several hundred truckloads of beets are received daily.

Even with the many fine improvements which have been made in recent years on beet receiving equipment there is still the problem of effectively screening out dirt, trash and rocks. Mechanical harvesting has generally increased the amount of foreign material transported to the receiving stations by the growers. This is not true in all instances but growers with large acreages, particularly in the northern Rocky Mountain section of the United States, must aim to complete their harvest by November 1 each year or otherwise take a chance of having their crop frozen in the ground. Faster machine harvesting increases the amount of dirt and trash going into the beet receiving stations. There is a definite need for improved

[1] Chief Agriculturist, Holly Sugar Corporation, Worland, Wyoming.

screening equipment. The new rubber Rienks screens have aided in solving this problem. It is suggested that wider and longer screens would help remove more foreign material and consequently reduce tare.

Reducing the flow of beets over the screen by slower dumping of loads will improve screening results. Improved dirt removal will also result from reducing the size of the opening between the hopper and elevator, causing a boiling action of the beets in the hopper.

The beet pilers at all of our large receiving stations have been equipped with stacker boom oscillators. A ½ H.P. electric gearmotor is used to drive this mechanism. Lever-type limit switches are used to stop the stacker boom at the desired point. This attachment has definitely improved storage conditions of beet piles because any dirt and trash which enters the pile is scattered, avoiding accumulation of foreign material in one place. The boom may be stopped at any point. This is important so that the outside edges of the beet pile can be built up to the desired height.

Most beet pilers are today equipped with hand operated tare takers which pass into the stream of beets and are removed quickly to obtain approximately a 30-pound sample. For many years there has been a demand for a fully automatic tare taker which would eliminate the human element in taking tare samples. One Silver piler in the factory yard at Worland, which handles about 30,000 tons of beets annually, was equipped with such a tare taker in 1953. This tare taker is powered with an electric motor equipped with stop switches. The piler operator presses the button that sets the tare taker into motion. It works very similarly to the hand operated tare takers available for Silver beet pilers. This fully automatic sampling device enters the center of the stream of beets directly below the shield as the beets come off the Rienks screen. The motor immediately reverses and the sample is swung around near the platform where the tareman then places the sample in the tare bag. This new tare sampling device has met with the approval of all concerned.

This tare taker could be improved by slightly increasing the horse power of the driving motor and somewhat heavier construction throughout. It has also been suggested that it be changed to dump the sample into a hopper. The sample would pass downward through a pipe into the tare bag at the ground level. This change would eliminate the tareman from being stationed on the piler and further decrease the human element in tare sampling. The factor of temporarily storing tare samples must be considered if the tareman is stationed on the ground. The present tarehouse provides effective and adequate storage.

Central tare houses are generally used throughout the Rocky Mountain district. These tare houses are equipped with two electric self-registering scales, beet washers, automatic top taring machines and a hot air dryer to remove excess water from the washed beets. This method of taring beets was prompted by the need for a more accurate means of determining tare and a shortage of labor. It has received approval from all concerned.

Ninety-five percent of the total 1953 crop at the Worland plant was harvested mechanically. Deliveries were exceptionally heavy beginning on

the first day of harvest. Machine harvesting has created problems of handling heavy daily tonnages as well as foreign materials when harvesters are improperly operated. Close cooperation between company and grower, coupled with improved screening on beet receiving machines, is essential in eliminating losses in beet storage piles and operating factories to capacity.

# Improved Beet Sample Taking With New-Design Pan

ART JOHNSON[1]

Because of the importance of obtaining as accurate a beet sample from growers' loads as possible, a new-type sample pan has been developed during the past two years by the agricultural staff of Holly Sugar Corporation.

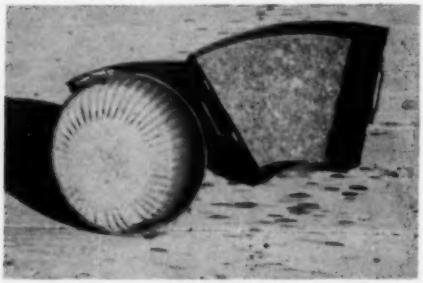

Figure 1

Figure 2

[1] District Agriculturist, Holly Sugar Corporation, Stockton, California.

Although the sample pan which had been in use at the California receiving stations for many years had been generally satisfactory, there appeared to be opportunity for improvement. Until two years ago we used the common, round, half-bushel, galvanized pan (Figure 1 at the left). By careful handling, the man taking the sample could get 20 pounds of beets or slightly more into the pan. For many years 20 pounds seemed a rather practical weight to use for the determination of tare and sugar content, although in some parts of Europe much larger samples are being taken—up to a hundred pounds or more.

**Figure 3**

The round pan has two unsatisfactory features:

1. It does not take a complete segment of the stream of beets as they come off the conveyor belt. As the round pan enters the stream of beets, it takes the first part of the sample out of a very narrow portion of the stream (Figure 3). This is followed by a true segment about the width of the belt. The last part of the sample is again taken out of a narrow portion of the stream as the pan completes its circuit by passing under the conveyor belt. If the round pan is simply brought in against the end of the conveyor belt so that pan and belt are tangent to one another and then brought back out again, the sample is even less satisfactory.

2. The size of the average truckload has in recent years increased nearly 50 percent. As a consequence of these two factors, a smaller fraction of the load and a less representative portion of the load came to be taken as a sample.

In order to correct this, a pan was needed which would take a more nearly complete segment of the stream of beets and a somewhat larger sample. The initial development of the pan is shown in Figure 1 on the right. Further improvement of the pan is shown in Figure 2. The length of the pan

**Figure 4**

**Figure 5**

should be as nearly as possible equal to the width of the stream of beets. A pan such as this will easily catch a 30-pound sample of beets and up to 40 pounds if desired.

The advantage of a pan of this shape is that it has a straight leading edge which is parallel to and coincides with the end of the conveyor belt as the pan enters the stream of beets (Figure 4). Also, as the pan passes

under the conveyor and out of the stream of beets, the trailing edge coincides with the end of the conveyor belt (Figure 5). Thus it catches a complete segment of the stream as it passes through.

Figure 6 shows the pan in position to be picked up and emptied.

**Figure 6**

# Basic Beet Piler Design and its Application to Construction

READ A. WILKINSON[1]

## Part 1—Design Requirements

Due to the expenditure necessary to purchase a modern beet piling machine the question reasonably arises as to what information is essential for the selection of the most economical and satisfactory unit.

If every receiving station were permanent and the acreage constant a special individual design would be necessary for every station in order to maintain a minimum overall receiving cost.

Since this condition very seldom occurs and a fluctuation of acreage per station results, a beet piling unit may be shifted to several different stations during the life of the machine. Therefore, only a general design may be formulated to determine the standard size unit which will handle the delivery of stations up to a certain peak. Identification of these sizes is by the width of the main elevator belt such as 38-inch, 42-inch or 48-inch.

Desipte the above there are many factors which will determine a final selection of the beet piling unit, many of which will differ depending on the existing climate, soil, growing conditions and receiving methods employed by the individual beet sugar companies.

Although the data herein presented pertain, for the most part, to piler design for southern Idaho much of the information or type of analysis is general.

Most cost analyses are based on tons of beets handled; therefore, consideration of capacity in design economy is of prime importance; consequently, this one factor will be dealt with more at length than any other. It is recognizable that beet storage is also a factor to be considered as are the many mechanical features which promote safety, simplicity in operation, and economical maintenance. However, in reality all have a material relationship to capacity.

In order to determine expected beet delivery it is essential that an analysis of pertinent data from an adequate number of past receiving seasons be made. This will include beet delivery, mechanization, precipitation, and existing beet piler capacities, all of which inter-relationships influence design characteristics.

The overall design of a beet piling unit may be subdivided into five separate catagories as follows:

1. Capacity; 2. Screening requirements; 3. Piling requirements; 4. Operational or mechanical requirements; 5. The economic factors. They will be considerd in this order.

### 1. Capacity

There are three factors which influence the rate of delivery. First and

---

[1] Agricultural Engineer, the Amalgamated Sugar Company, Nampa, Idaho.

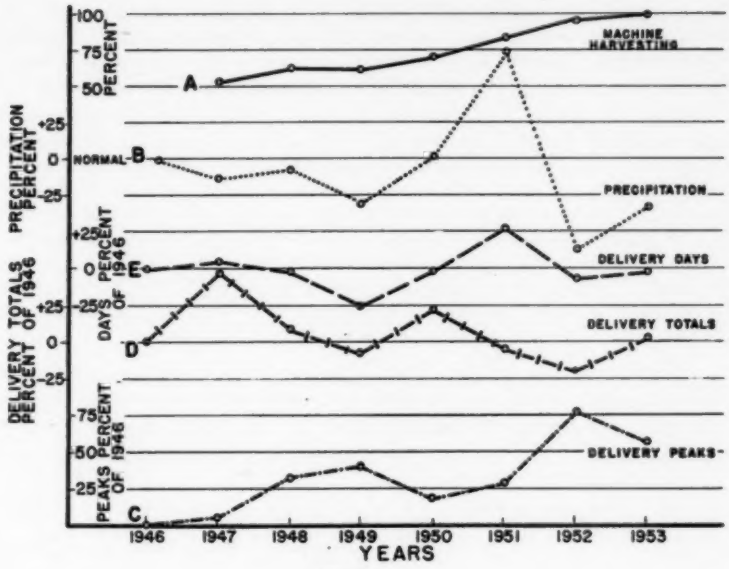


**Figure 1**

foremost is the use of machines in harvesting the beets, second the weather and third the size of crops harvested.

Graphs have been plotted from compiled data of these three factors for the years 1946 through 1953 in the Nampa-Nyssa districts and the following deductions may be made as shown in Figure 1.

1. An increase to 98 percent in mechanical harvesting is shown on curve A.

2. Curve B portrays the variation in precipitation during the same period wherein it has been below normal for the majority of years.

3. Curves C, D and E are based on the year 1946 from which the following deductions may be made: A gradual increase in delivery peaks have occurred since 1946, which directly follows the increase in mechanization. These peaks are lowered slightly in years of high precipitation and large beet crops, but not sufficiently to eliminate the continual rise.

The fluctuation in total days harvest for each year as shown by Curve E follows quite closely the precipitation shown by Curve B and has gradually decreased.

In Figure 2, delivery by the week was plotted in three characteristic years in which approximately the same tonnage was delivered and the precipitation was about the same. From this information it may be deduced that the time of peak delivery has remained about the same. In fact, out

of the eight years investigated only one peak changed radically from the general pattern, and that was the year when the precipitation was the highest above normal. As will be noted from these curves, also the peak tonnage reached has increased each year as has the percent of fall mechanization.

This increase in peak delivery is extremely important with regard to piler design as it is this increase which affects the capacity and selection of the pilers used, since piler peaks automatically follow total peaks where the same equipment is used. While this increase in peaks has been adequately handled in the past due to the 56.5 percent average piler utilization, it will not be possible to continue to handle it in the future as the maximum capacities of the units are rapidly being reached. This is understandable when an analysis is made of past receiving reports which show that average piler peaks have increased 16 percent in the last four years, as compared with weekly delivery peaks, which have increased only 7.4 percent.

For example, in 1953 the piler utilization for the large delivery stations reached a peak of 89.5 percent with the maximum being reached just before noon and again before closing time. If the maximum capacity were

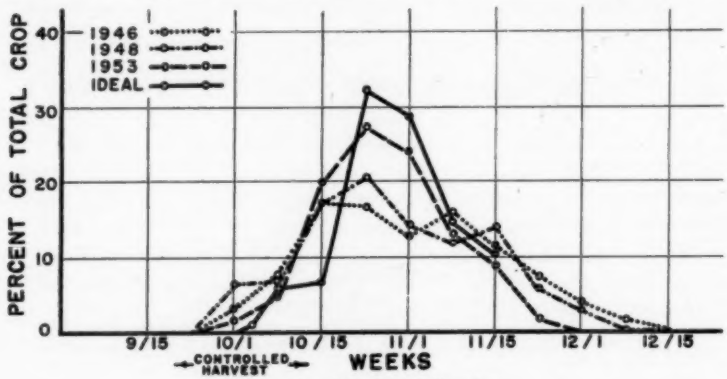


**Figure 2.—Weekly deliveries.**

maintained during the entire day, the situation would be extremely congested, thus curtailing the growers' harvest operations. Such a condition cannot be allowed, and changes are necessary to alleviate it, either in harvested acres or piler design.

With mechanical harvesting increasing and the growers delivering beets more rapidly, the question arises as to what the ultimate delivery rate will be, or at what point should it be controlled. As seen in Figure 2, the time of delivery has been materially reduced between the years 1946 and 1953, which is inverse to the peak delivery trend. Therefore, it becomes necessary to determine whether it is desirable to increase or decrease the time for delivering beets. The determination of this factor is essential because upon it rests the conclusion as to whether piler capacities should remain as they are or be increased.

Since design, as discussed in this paper, is predicted for the most part

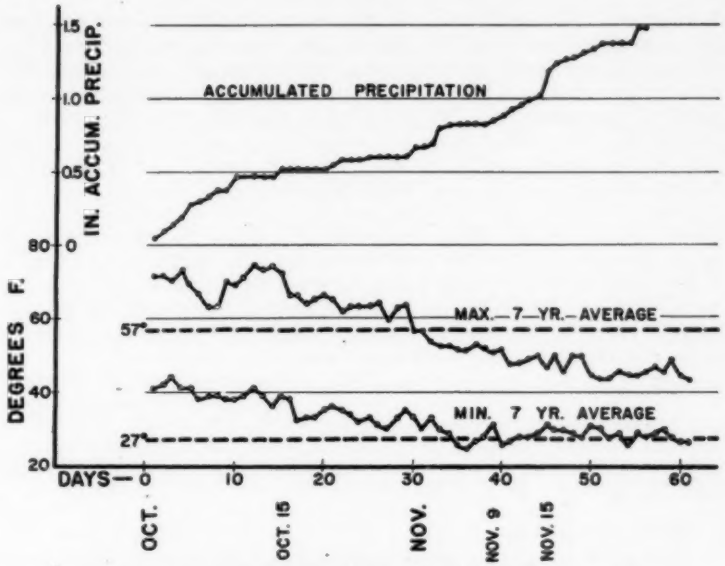


**Figure 3.—Temperature and precipitation—7-year average.**

on the piling of beets, it is necessary to determine the time period when it is most satisfactory to pile for storage. Factors affecting storage consist of maximum and minimum temperatures and precipitation; therefore, the 7-year average of these for the Nampa-Nyssa district is plotted in Figure 3.

Ideal temperature variation for sugar beet storage in southern Idaho is between 57° and 27° F., when precipitation is low and intermittent. In accordance with these limiting factors, an analysis of the curves indicates that during the fore part of the season the maximum temperatures are the determining factor and in the latter part of the season the minimums are. Since there are only a few available days between these limits, a large latitude must be included.

Because the expected dry and warmer atmospheric conditions are more favorable for harvesting during the piling period than the cold and wet conditions, the shift should be in that direction. Further observation of the curves indicates that the final maximum temperature drop occurs on October 15, thus establishing a date for the beginning of unrestricted harvest and pile storage. The minimum temperatures become unfavorable November 9, which will determine this to be the latest pile date. The precipitation curve indicates that there is a period starting October 10 through November 8 whereby very little precipitation falls; thus, the 26-day period from October 15 up to and including November 9 is satisfactory as far as precipitation is concerned.

Since it is necessary to start harvest two weeks before the beet storage season begins a certain percentage of the beets necessary to operate the fac-

tories must be harvested. This will approximate 1 percent per day, leaving the other 87 percent to be harvested in the remaining 26 days. Assuming 1953 as a normal year with 98 percent of the harvesting being done mechanically, it can serve as a base upon which the pro-rated increase can be applied. The delivery for a 26-day period is, therefore, plotted in Figure 2 to show the comparison. From past delivery data we have concluded that peak station delivery for the 48-inch pilers will amount to 1.33 percent of the delivery for the peak week, which amounts to approximately 4,000 tons per day, or a 12 percent increase over the present peak delivery for the present 48-inch pilers. This increase may, of course, be taken care of by longer station hours, but the piler utilization data would indicate that it is an increase in hourly capacity which is necessary to reduce congestion and not more hours. Therefore, we may conclude that the capacity in tons per hour of pilers at peak stations should be increased by the above amount to handle approximately 340 tons per hour.

**2. Screening Requirements**

The modern piler requires a screen which will operate with greater efficiency to eliminate trash, dirt, rocks and clods. It is necessary that this be accomplished with a minimum amount of small beet loss and interference from mud.

**3. Piling Requirements**

Storability of beets depends upon many factors, among which are a few features which can be built into a beet piler: namely, the ability to automatically spread the beets and escaping trash uniformly on the pile face. Also, the ability to build piles of different widths and heights without cutting down capacity from beets rolling back on the piling boom belt is important. This is essential in order that piles may be built for either natural or artificial ventilation.

**4. Mechanical Requirements**

There are many features on pilers which are desirable in that they reduce operational cost, maintenance, and provide convenience and safety.

A piler must be mobile and compact as it is necessary to move these units at times, especially from pile to direct car delivery. This requires a minimum amount of weight per square inch of track area on the ground. Adequate and positive steering is also desirable not only to aid in maneuverability, but to reduce the length of piling areas necessary.

It is also essential that operation and controls of a piling unit be simply arranged for safety, and that consideration be given to minimum labor requirements for both operation and repair. Power and maintenance costs should also receive major consideration.

All possible safety features, with regard to drives and electrical installations, should be incorporated in the unit.

Roomy tare houses and provision for taking tare samples are desirable as are arrangements on some pilers for both side and end dump trucks.

Initial and operational costs per ton of beets handled should be kept as low as possible with regard to all sizes of beet pilers.

**Conclusions**

1. Design of sugar beet piling machines cannot be confined to a single station, but will, of necessity, be adequate to handle peak capacities for a group of different sized stations.

2. Pilers at present have been resolved into three different sizes with 38-inch, 42-inch, 48-inch width feeder or elevator belts. This, however, could be reduced to two, the 42-inch and 48-inch, provided an option were allowed wherein a piler could be purchased with one or two platforms.

3. The increase in mechanical beet harvesting is one of the main contributing factors necessitating a change in modern beet piler design.

4. Delivery peaks have increased sufficiently due to and along with the increase in fall mechanization to tax the present capacity of many pilers. These peaks are slightly affected by precipitation and size of crop.

5. The date when peak periods of delivery occur has not changed because of the increase in percent of fall mechanization, but a reduction in days of harvest has resulted.

6. Piler peaks follow delivery peaks and, therefore, directly affect piler design capacity.

7. In the Nampa-Nyssa district the ideal piling period in which to receive beets extends from October 15 through November 9, a 26-day period. Peak deliveries for this period, considering an average crop, would increase 12 percent, thus increasing the required peak capacity of a beet piler to approximately 340 tons per hour.

8. Modern beet pilers should have certain mechanical features incorporated in their construction to increase the efficiency of screening, and versatility of piling. Also of major consideration are features which reduce operational and maintenance costs, provide safety and simplicity in operation, lend to mobility and compactness.

9. Unit initial and operation costs per ton handled should be kept to a minimum.

---

## Part 2—Meeting Design Requirements

J. G. STONE[2]

The first successful portable sugar beet piler was designed and built by the Ogden Iron Works Company in 1925. During the intervening years many improvements in beet pilers have been made to meet changing harvesting methods. Three principal objectives have been constantly kept in mind, namely:

1. Greater capacities of pilers
2. Better dirt and trash removal
3. Improved condition of beet piles

In addition to the above basic objectives, the mobility of the machines, safety features, reduction of operating crews, lower maintenance, etc., have also been uppermost in the minds of the engineers.

**Greater Capacity of Beet Pilers**

To achieve increased piling capacity several important factors have been given consideration. Capacity is directly related to the size and number of

[2] Secretary of Ogden Iron Works Company, Ogden, Utah.

loads of beets which can be dumped, elevated, screened and piled, in a given period of time. Several points in the design of a beet piler may be mentioned whilch make for the handling of more and larger loads per hour or per day:

1. Proper platform design; 2. Ample beet hopper capacity; 3. Faster and smoother dumping of loads; 4. Arrangement of dirt conveyor for ease in getting dirt and trash into the grower's truck; 5. Width and speed of feeder and incline conveyor belt; 6. Correct relationship of screen size and speed of screen rolls with respect to tonnages being handled. Other points could be mentioned.

The use of pilers with double platforms has enabled the machines to handle approximately 30 to 35 percent more loads than where single platforms are used. The use of an improved hoisting mechanism has also lessened the dumping time. In recent years our pilers have been equipped with hydraulic hoists which give smoother dumping of the truck bodies and at the same time provide almost foolproof operation.

Longer and deeper beet hoppers facilitate dumping of large loads in less time, thus allowing the truck to get off the platform and under the dirt belt without delay, which permits the following load to be made ready for dumping sooner. The dirt conveyors for delivering the dirt and trash from the dirt hopper to the farmer's truck have also been improved to afford greater speed.

Increased piler capacities have also been obtained by the use of wider feeder and incline conveyor belts, at the right speeds. The screening unit must also be of the proper size, and run at the correct speed in order to handle these greater tonnages. They must also provide the best possible removal of dirt, trash, clods, etc., from the beets.

Another factor tending toward increased piling capacity is the speed and ease with which the piler can be moved when a new segment of the pile is begun.

**Better Dirt and Trash Removal**

Many types of beet screens have been used over the years. Some have been fairly effective under ideal harvesting conditions and not too effective when conditions have not been ideal. Changing harvesting methods have also required new and better types of beet screens. With the introduction of mechanical harvesting of beets new problems presented themselves which were not noticed when beets were hand topped and hand loaded. The present beet screens have to remove the dirt and trash, as well as rocks, and other foreign matter which are brought in with the beets, consequently the screen is subject to more severe usage. The latest development to overcome these problems has been the use of rubber screen elements. These were introduced to the trade some six years ago. The use of molded rubber screen elements on the screen shafts made it possible for rocks and other foreign objects to pass through the screen without jamming and clogging it. Several other advantages were also noted, among which might be mentioned decreased weight of the screen rolls, smoother operation, less vibration, less bruising of beets, etc.

The screening of beets was further improved by the use of the reverse screen rolls strategically located in the screen unit. By the use of reverse rolls at the proper points in the screen and by providing screens of ample width and area so that the beets could spread out and allow the dirt and trash to come in contact with the screen rolls, better and greater dirt and trash separation has been obtained.

While the use of rubber screen elements is very effective in dirt and trash removal, in some districts there has been a tendency for the reverse rolls to pull small beets through the screen along with the leaves and trash. This problem seems to have been more pronuounced in certain areas where mechanical thinning and closer spacing of beets prevail, consequently, with the increase of spring mechanization, a problem has developed which must be solved. To accomplish a reduction of beet loss a proper relationship in speeds between rolls running in the forward direction and the rolls running in the reverse direction was made. Thick-fingered rubber screen elements and a combination of steel and rubber screen kickers were also used on the reverse rolls. All of these have brought about an improvement in the beet screen unit and tended toward a solution of this particular problem.

Another desirable change introduced on pilers during the past two years consists of adding an independent motor for driving the screen unit. This enables the screen to be driven separately from the incline conveyor, thus providing a feature which was not available with the former driving method. In the single unit pilers of the 1953 model an independent motor drive was used for the auxiliary dirt belt, which made possible the automatic stopping of the auxiliary dirt belt beneath the screen when the main dirt belt was discharging into the grower's truck. Thus, the dirt from a following load would not become intermingled in any way with that of a preceeding load.

**Improved Condition of Beet Piles**

In the design of beet pilers, much thought was given to features which would improve the condition of beet piles, to avoid losses occasioned by beet spoilage while in storage. In addition to providing the best possible screening and trash removal, other factors such as the proper length of the piling boom, depth of beet pile, distribution of beets across the face of the pile, etc., all have a bearing on how well the beets will keep during the storage period.

The piling boom lengths vary from 50 to 60 feet according to the type of piler furnished. With the 48-inch double unit, double platform pilers the boom can be somewhat shorter than that of the single unit-type pilers. On the 1953 model, single unit machine, with double platforms, a 55-foot boom length was found to be the most desirable. The width of the pile at the base is approximately 134 feet to 140 feet, and the depth of the pile about 22 feet. All piling boom conveyors are motor driven from the head shafts, as it has been found that this location of drive gives the best belt operation.

For many years the piler booms on Ogden Iron Works Company pilers have been motorized for swing, and for the past ten or twelve years, auto-

matic boom swing control has been furnished on all of our pilers. The electrically controlled reversing boom mechanism has time relays so that a predetermined pause at each end of the boom swing is obtained before the mechanism automatically reverses the direction of swing. This pause at the end of the boom swing eliminates the serrations or valleys that previously occurred in the sloping sides of the pile where the boom was immediately reversed without a pause at the end of the swing. Thus, there is less exposed surface on the sides of the pile.

The most important advantage, however, of the automatic boom swing is the even distribution of any escaping dirt or trash across the face of the beet pile. This avoids any concentration of trash and dirt in one place, thus minimizing one of the chief causes of beet spoilage.

**Improved Mobility of Piler**

An outstanding feature of the Ogden Iron Works piler is the ease and speed in moving, when necessary to begin a new segment of the pile. This enables the crew to make shorter and more frequent moves, thus keeping the top of the beet pile smooth and free from valleys. This is important, especially in those piles where the beets remain in storage for extended periods of time before being processed at the factory.

This ease in moving is made possible by the hydraulic steering, as well as hydraulic raising and lowering of the feeder and the platforms.

All of the pilers are mounted on crawler tracks which are driven on both sides of the machine through a differential, thus giving proper traction under all conditions. The width of these tracks and their length is such that the weight of the machine will not impose a greater unit pressure on the ground than is desirable for good mobility. The steering wheels are also of ample tread width so that the unit pressure on them is not excesive.

**Safety Features**

Safety features in design and construction have ever been uppermost in the minds of the engineers. All motors are provided with magnetic switches, with circuit breaker protection ahead of them. All wiring is of the rubber-covered cord or cable type, and is placed in conduit. The machines are also properly grounded. Safety guards are placed over all drives, chains, gears, etc., to prevent injury to employees and others working or moving in and about these machines. If the machines are to be used for night operation, or during periods of darkness, they are furnished with electric lights adequate for this service.

**Future Improvements**

Notwithstanding the great strides made in improving beet pilers from their inception in 1925 to the present, each year brings to light new ideas and new needs pertaining to improved design and construction. If greater piling capacity is required, ways will be found to accomplish this. Ogden Iron Works engineers are open-minded and gladly welcome any suggestions either as to specific improvements, or as to the end result desired. They are willing to cooperate fully in any manner that will foster the design and construction of better pilers.

# Sugar Beet Storage Problems

L. R. Cool[1]

The ultimate goal the sugar industry constantly strives to attain is to store sugar beets for long periods of time with a minimum of weight and sugar loss. The problems arising out of such storage will vary somewhat from area to area, but in general they are the same, at least to the agriculturist who is charged with the responsibility of delivering about as many beets to the factory as were paid for.

Of course the greatest cause for loss is spoilage, and with our present day knowledge of this problem, there should never be any loss from spoilage. We in the northern Rocky Mountain area have experienced a wide range of varying, deterimental conditions and have thus learned to cope with practically all of them. To begin with, we work our pile grounds early and keep them cultivated all summer, following this with a leveler just before campaign to level and firm up the ground. This of course eliminates all manner of vegetation and trash which could start spoilage.

In starting the building of the pile, the boom is raised approximately four feet and the pile started by moving the boom constantly from one side to the other. When this space has been filled, the piler is moved a short distance ahead and the boom raised accordingly. The pile is built to the desired height in the foregoing manner; however, the first piled beets are not allowed to become completely covered. This is accomplished by moving the piler ahead when beets start to roll back over that portion which was first piled. The piles are about 18 feet in height, which size and shape is governed more or less by the piling ground available. All piles are so built and placed that they may be shoveled into from any direction to reach a serious hot spot rapidly should one occur.

Continuing the building of the pile, the sides and top are kept as uniform as is possible so that snow will not accumulate in the valleys, which are generally caused by moving the piler too far at a time. This accumulation of snow has been known to thaw and run into the pile, causing the pile to freeze from top to bottom when temperatures dropped. Alternate freezing and thawing have caused serious spoilage in some of the piles.

While beets are flowing off the boom into the pile, it has been demonstrated that it is important to keep the boom moving in order to prevent an accumulation of dirt and trash in one spot. This accumulation forms a cone which seals out the air and invariably spoilage will start in a very short time. (Human nature being what is is, we have learned not to trust the operator to keep the boom moving. Boom oscillators have been installed on some of the larger stations or where the pile will be in storage for a longer period of time.

The condition of the loads of beets being delivered is, of course, most important as good preparation and operation cannot cure all the ills con-

---

[1] L. R. Cool, District Agriculturist, Holly Sugar Corporation, Hardin, Montana.

tained in a bad load of beets. Naturally no frozen beets are allowed to enter the pile. When beets become frozen in some of the areas which are served by pilers only, another small pile is made or they are stacked against the outside of the pile where they can be reloaded promptly. This problem of beets freezing in the field is becoming less and less acute as mechanical harvesting increases.

In regard to loads of beets delivered by a grower containing excessive amounts of clods or trash, the offender is called on with the view of helping him correct the condition. In cases where the grower will not cooperate, the load is rejected; but in most cases, a friendly and helpful visit gets the job done. When receiving loads containing excessive amounts of trash, it often helps considerably to slow the piler so that beets do not pass over the screen too rapidly and tend to carry trash on over the reverse rolls. Also, the amounts of beets being fed into the piler should be restricted by hoisting the truck box a little at a time. This will keep the screen from being overcrowded and will result in more effective removal of trash by the screen.

One condition that cannot be corrected in most cases is that which occurs when freezing temperatures are encountered for several days and the face of the pile becomes frozen each night. This is the case in which lack of room in the pile ground will not allow the piler to be moved ahead to leave a space so as not to cover up the frozen part of the pile. These piles are given careful attention and, at the first signs of heating, large holes are dug into the pile by hand labor to get air to the affected spot or, in more serious cases, a power shovel is moved in and the whole section of the pile is removed and processed before serious deterioration can take place.

The last two harvest seasons have been extremely warm and temperatures have ranged between 80 and 90 in the daytime and 40 and 50 at night. These temperatures have caused a lot of top growth in the piles and no doubt have been responsible for the major part of our weight and sugar shrinkage. By careful attention as mentioned above spoilage is avoided.

Present day loading equipment is highly mobile and it is for this reason, as was stated that no loss should ever occur in a pile on account of spoilage.

## Summary

Experience has taught some basic rules which should be followed when storing sugar beets. These are:

1. Grade pile grounds to produce clean and level grounds.

2. When building the pile, start with boom lowered and avoid covering the first piled beets by raising boom and moving ahead slightly.

3. Boom should be kept moving constantly to avoid accumulation of trash in one spot.

4. Sides and tops of pile are kept uniform to avoid valley which will collect snow.

5. A close inspection of all loads should be maintained so as

not to allow frozen beets or loads with excessive trash and dirt to enter pile.

6. Slow down the piler and restrict the amount of beets being fed into the piler so that the screen can be more effective in trash removal.

7. Locate and build piles in such a manner that the center may be reached in a short time with reloading equipment should any serious trouble develop.

# Adapting the Marbeet Midget Beet Harvester to Experimental Plot Harvest

R. E. JOHNSON[1]

Two years ago it was decided to adapt the Midget Harvester to plot harvest. This endeavor was necessary as it was becoming more difficult to acquire labor, and especially experienced labor, to harvest plots. The Midget was chosen as it lent itself more readily to plot harvesting and was becoming more generally used in California. Accordingly, Luke Schmidt of the Blackwelder Manufacturing Company incorporated the ideas of L. A. Kloor, research agriculturist, Holly Sugar Corporation, and the author into the design of the additional equipment needed.

The following equipment is needed:

1. A chute attached to the end of the harvester elevator which diverts the beets into the weighing basket.

2. A weighing basket 2 feet x 2 feet x 2 feet and made of ¼-inch mild round steel. This size basket will hold 250 pounds of beets. The basket is fitted with a bail which rests in two hooks welded to a movable shaft which holds the basket rigid while being filled.

3. A 300-pound capacity spring scale attached to the basket.

4. A tripod which is clamped onto the two sides and rear of the cart.

The following procedure is used:

The harvester is driven into the plot and continues until the elevator is full of beets. It is then stopped and a sample taken. The harvester is then driven to the end of the plot and stopped when all the beets from the plot are run through the topping discs. The beets are run into the basket and if desired another sample taken at this time. The beets are weighed and the weight recorded. The basket is emptied by means of a trap door in the bottom of the basket. The beets fall to the floor of the cart and are run out into the truck while the next plot is being harvested.

Five men are needed to conduct the harvest. These consist of a tractor driver, two men on the cart to collect the samples and weights and dump the beets, one man following the cart to pick up any beets missed by the pickup wheel and tie the sample bags, and a truck driver.

The primary advantage lies in the fact that it is possible to harvest with a smaller crew, the output per man hour being almost twice that of a harvest conducted entirely by hand. The equipment will fit on any Midget harvester. The Plot harvester has been used for two years in California and one year in Wyoming and has proved to be very satisfactory.

---

[1] Associate Agronomist, Holly Sugar Corporation, Tracy, California.

# Conserving and Handling Beet Tops

E. L. SWIFT[1]

Under the varying conditions of the widely scattered operations of growers of beets for the American Crystal Sugar Co., we find many methods of conserving and handling beet tops. Beets contracted to our company are grown in ten of the western states, from within twenty miles of the Canadian border to within a few miles of the Mexican border and from California on the west to Minnesota on the east. Beets are produced under conditions dependent entirely on rainfall and on irrigated farms; from below sea level to areas more than 7,000 feet in elevation. It is not surprising that we find beet tops utilized in many ways, depending on method of harvesting the crop, crop rotation and availability of equipment, land and livestock.

When we think of conserving and handling beet tops we generally think of feeding the material, or at least windrowing or shocking the tops for livestock pasture. However, in many of our areas it has been found that the most practical manner of conserving beet tops may be to work them into the soil for their fertilizer value. The tops may be beaten off and worked into the soil immediately, or plowed under after the regular beet harvester. So far as our overall company operations are concerned, in 1953 approximately 71 percent of all beet top acres were plowed under, this representing 102,971 acres of sugar beet tops.

In our East Grand Forks, Minnesota, district, the practice of plowing under beet tops after beet harvest has been common since 1935 or 1936, as well as the practice of plowing under a heavy crop of sweet clover. The three-year rotation is grain with sweet clover, the second year plow down the clover and fallow, then beets the third year of the rotation, plowing under the beet tops. It is significant that the average yield of all beets delivered to the East Grand Forks factory for the 11 years prior to and including 1936 averaged 7.19 tons per acre as compared with an average of 10.21 tons per acre for all beets harvested since 1936. These yields were on non-irrigated fields. Certainly a part of this increase in beet yields may be attributed to the beet tops plowed under, and their effect on the fertility and structure of the soil.

Studies by Dunn and Rost (1)[2] of the University of Minnesota, in 1946, showed a cash value of $21.94 per acre for the three fertilizer elements in the beet tops from a 15-ton crop of beets. At today's prices their value would be increased to more than $25.00 per acre, this in addition to the value of the organic material of the beet tops, which may be considered to be comparable in value to the fertilizer elements in the tops. It was found that 12.6 ton of green tops was saved when the 15-ton beet crop was harvested.

Here in our Missoula district, with which we are most familiar, many of our beet growers who do not have manure for their beet land or enough land for any sort of a rotation grow beets year after year applying only

---

[1] Manager, American Crystal Sugar Co., Missoula, Montana.
[2] Numbers in parentheses refer to literature cited.

commercial fertilizer and plowing under the beet tops. Such a practice is probably not to be recommended, but the results of this practice have been good. We find that such fields have steadily improved in so far as yield and soil structure are concerned, yields from five of these fields for the past ten years being listed in Table 1. Many such fields have been in beets regularly for the past 25 years.

**Table 1.—Fields Almost Continuously in Beets—No Organic Fertilizer Except Beet Tops Plus Commercial Fertilizers (200 Pounds Ammonium Nitrate and 160 Pounds Treble Superphosphate**

| Year | Bailey & Erickson 38 Acres | Severns & McGinnis 8 Acres | H. D. Hoblitt 14 Acres | Chas. Talbot 24 Acres | Ray Morris 46 Acres |
|---|---|---|---|---|---|
| 1944 | 14.18 | 13.34 | 15.84 | 17.70 | 10.85 |
| 1945 | 15.20 | 15.50 | 18.40 | 19.60 | 12.80 |
| 1946 | 16.30 | 15.50 | 19.30 | 21.40 | 13.35 |
| 1947 | 15.90 | 17.70 | 20.50 | 22.80 | 15.40 |
| 1948 | 14.90 | 17.45 | 16.57 | 20.41 | Grain |
| 1949 | 12.80 | 16.04 | 18.13 | [1] | Alfalfa |
| 1950 | Lettuce | 15.70 | 18.60 | [1] | Alfalfa |
| 1951 | 13.48 | 15.60 | 19.51 | [1] | 14.47[2] |
| 1952 | 16.11 | 15.59 | 21.46 | [1] | 16.30 |
| 1953 | 18.22 | 19.04 | 19.80 | [1] | 20.66 |

[1] Land bought by another grower, and two contracts put together, but yield well in excess of 20 tons each year.
[2] No green material plowed down, only the alfalfa roots plowed under in the spring before beets.

Our second most common method of conserving beet tops is to pasture them off the beet field, after the beet harvest, a practice which generally utilizes less than half of the total feed value of the tops. This method of feeding beet tops is popular because it requires less labor. In our entire company operation for 1953 approximately 21 percent of all acres of tops were pastured off the field, this representing 29,720 acres of beet tops.

In a normal season, the practice of pasturing tops off the beet fields is very wasteful because of losses from leaching, trampling and drying. If the season is wet a large part of the feed is lost through leaching and trampling into the soil—which also compacts the soil so it is difficult to work the following season. If the fall is dry the beet tops dry and shatter so that the leaves are mostly lost. Many of our growers, however, feel that the ease of pasturing tops more than outweighs the losses in feed value and the difficulties from scouring and choking. The beet tops to be pastured may be handled in any of several manners after the beet crop is harvested, either leaving the tops where they fall after the harvester, windrowing them with attachments on the beet harvester, windrowing them with a side delivery rake after the harvester or shocking them in the field by hand labor. If the tops are shocked or windrowed they keep better and are more available to stock if snow covers the tops.

To evaluate the gain which could be put on cattle in our area by pasturing tops, on our Missoula farm in 1952, forty acres of beet tops were pastured off the field, from beets yielding fourteen tons per acre. Some 62

steers were put on this beet top pasture October 1, and the number of steers was gradually increased so that October 31 we had 182 steers on the tops. This number of steers was continued on the tops until November 19, when they were put in the feed lot. The beet tops were windrowed with a side-delivery rake after the International beet harvester. These tops were pastured under near perfect condition, by a large number of cattle and during ideal weather. The average grower during the average season realizes less than half of these gains as shown by this test. (Table 2.)

**Table 2.—Gain from 40 Acres of Beet Tops (14-Ton Beets) by "Pasturing Off."**

| | |
|---|---|
| Total days steers on beet top pasture | 6,423 days |
| Total grain on beet tops | 9,250 lbs. |
| Gain per day per steer. | 1.44 lbs. |
| Acreage of tops pastured | 40 acres |
| Tonnage of beets from which tops were pastured | 560 tons |
| Pounds gain per acre of tops | 231 lbs. |
| Pounds gain from tops per ton of beets | 16.8 lbs. |

In our Missoula area, beet tops for pasture sell for only 75 cents to $1.00 per beet ton or 10 cents per head of cattle per day on tops. If these tops had been sold for these figures they would have netted us $560.00 at $1.00 per ton or $642.00 at 10 cents per steer per day—plus the value of the manure.

When it is remembered that practically all of the fertilizer in the beet tops passes through the steer as manure, some 87 percent of the nitrogen, 87 percent of the phosphorus and 90 percent of the potassium, it appears that more than 88 percent of the total fertilizer value of tops from the 15-ton crop mentioned by Dunn and Rost, or $22.50 per acre, is returned to the soil, in addition to the gain put on the steers. A large part of these fertilizer elements may be lost before being worked into the soil. In areas where livestock are available, and weather suitable, pasturing beet tops off the field after windrowing them, and then discing or plowing to mix the soil and manure would be a worthwhile practice—not as good as making ensilage out of the tops but better tthan plowing the tops under for their fertilizer value.

Our best, and least common, means of conserving beet tops is by making them into ensilage. This method of utilizing tops is not affected by weather and the feed is available for a long feeding period. Over our company operations, tops from approximately .6 percent of all beets were utilized for ensilage, this representing 830 acres of beets.

Morrison shows a potential gain of 100 pounds of meat per 700 pounds of t.d.n. and as average beet top ensilage is 14.9 percent t.d.n. we can figure that one ton of ensilage will put on 21.5 pounds of gain. This is indeed cheap feed, if the beet tops can be handled economically at harvest time, and if equipment is available to do a proper job of saving the tops.

In our Mason City, Iowa, area, where the Scott-Urschel harvester is the common means of harvesting the beet crop, one of the growers built a beet top elevator which conveyed the green tops to a 4-wheel trailer which is pulled behind the harvester. The load is pulled off the tractor into the

silo, which consisted of a concrete slab—80 feet by 24 feet—with plank sides to a height of 8 feet. The ends were left open. The tractor and trailer drive over the tops with subsequent loads, and out the other end, which packs the material. A layer of tops was laid down, then a layer of corn silage to soak up the juice from the tops, and then more tops. Some 200 tons of excellent beet top ensilage was made, the silo filled to about three quarters capacity. The harvest of beets was not delayed as two trailers were used, and the amount of extra labor was very small, and a very clean product is available for feeding.

An Allis-Chalmers hay chopper was used to remove as many petioles and leaves as possible from beets at Missoula, blowing the green material into a trailer. Some difficulty was encountered in dropping the sickle cutter bar of the chopper low enough to pick up the leaves as the frame for the bar knocked over beets. By putting on "lifter guards" most of the leaves were lifted so that the cutter bar removed them. Recovery of green material averaged 1,250 pounds per ton of beets until the first frost when the yield of tops was reduced to only 650 pounds per beet ton.

In the Rocky Ford, Colorado, area a Lundell hay chopper was used to harvest the beet tops, this chopper resembling a rototiller with three-cornered cutting blades welded to the arms. Three rows are topped at a time. The top and crowns of the beets are cut off near the leaf scar line, and all thrown into a worm scroll which feeds the materials into a blower that blows it into a trailer behind the chopper. Top recovery was good, and with proper care in adjusting the machine there is little dirt in the silage.

All of the standard hay choppers are being used to pick up beet tops which have been windrowed six to eight rows behind the beet harvesters. These machines all work well and recover most of the tops, but excessive amounts of dirt are picked up with the tops. Where the tops are siloed green, it is usually necessary to use straw, corn ensilage, or some such material to retain the juices. Dried beet pulp is the best material for this purpose, each 100 pounds of pulp retaining up to 1,600 pounds of juice. Our growers have found that 20 to 30 pounds of dried pulp per ton of wet material will hold all juice, and make the best ensilage of any method tried as yet. It has been found that by field curing the tops one or two days after the harvester that the weight of tops to be handled is reduced by almost half, but valuable feed is also lost. If a corrugated roller is used to pack down the soil onto which the tops are ejected from the harvester a much cleaner product is received for feed.

Our most successful feeders here in Montana believe that the best method of handling beet tops is to pasture about half of their beet top acreage, having enough cattle to clean up the tops before November 15, then put the cattle in a dry feed lot, and feed a balanced ration utilizing the other half of the tops as ensilage.

As this is written we know of no really successful commercial beet-top harvester which is available on the market, one that with little manpower does a good job of topping the beet, recovering the top without dirt, and loading it in a trailer or truck either whole or chopped. The beet roots are

easier to harvest after the tops are removed—another reason to harvest the tops as a separate operation. It would appear, from looking at the figures above, with less than 1 percent of all beet tops in our company saved as ensilage, that such a commercial machine would find a good market. If our company operation is representative for the nation as a whole, only 1 percent of the tops from the million beet acres of the country are utilized to full advantage as ensilage. Certainly there is a tremendous market for beet-top harvesting equipment, when such is available.

## Literature Cited

(1) L. E. DUNN and C. O. ROST.
1946. Yield and nutrient content of sugar beet tops, Agricultural Experiment Station, University of Minnesota.

# Irrigation of Sugar Beets

IVAN D. WOOD[1]

## Introduction

Irrigation as an art has been practiced for more than four thousand years in the old world and perhaps for nearly two thousand years in some parts of North America. Remains of ancient irrigation systems in Arizona indicate that a surprisingly large population in twenty communities was supported by irrigation water from the Salt River. Many of the ancient canals still remain and estimates of their age place the construction period about 700 A. D.

Slightly more than 100 years ago Mormon settlers in the Salt Lake Valley turned the water of City Creek onto a field of potatoes. This was possibly the first irrigation by white man in the United States.

## Land Preparation

A certain amount of land preparation is always necessary if gravity methods of irrigation are to be practiced. Within recent years the science of land preparation has been greatly improved. At the present time the advent of large machinery has made possible extensive leveling operations which would not have been feasible at one time.

Space does not permit an extensive discussion of land preparation practices. It should be said, however, that the tendency at present is toward producing flat grades or entirely level fields. The idea of running the water downhill in furrows with considerable slope is no longer thought to be good practice. Swiftly running water produced erosion and is extremely wasteful of both soil and water.

Land preparation for irrigation does not consist entirely of the so-called leveling process. It embraces also surface and underdrainage. The fields to be irrigated must be protected from flood water arising in the surrounding higher areas. Excess irrigation water must be removed and underdrainage provided to prevent the water table from destroying crops.

## Method of Water Application

There are four ways of applying water to land, namely:

1. Spreading it in thin sheets over the surface.
2. Running it in furrows.
3. Sprinkling it upon the surface, like rain.
4. Sub-irrigation.

Spreading water over the surface of the land in thin sheets was practiced by many early pioneers. They usually cut the ditch banks and allowed the water to run by a method called "wild flooding." This was a wasteful and inefficient method because so much of the land was unevenly irrigated and water was wasted. Fields were usually poorly prepared, high spots got no water, and low spots got too much.

---

[1] Irrigation Engineer, Soil Conservation Service, Denver, Colorado

Modern flooding methods are efficient and economical of water. In some cases a flat area is diked and flooded to a predetermined depth. This is known as the basin method. The border dike method is more commonly used. A dike is built on either side of a strip of close-growing crop, such as pasture, hay or grain. Water is introduced at the high side of the strip and allowed to flood it in a thin sheet which passes over the surface in a predetermined period of time. This border dike method is practiced in almost all irrigated areas and is highly recommended when the work is properly designed and constructed. It is important that the flow of water be carefully adjusted to the width of the border strip and the slope of the ground.

When water is applied in furrows, it is also important to control the flow, dependent upon the slope of the ground. It seems that the soil to be irrigated makes very little difference as far as erosion effects are concerned. A rule of thumb which has been determined by more than 2,000 irrigation trials indicates that the size of the furrow stream in gallons per minute can be determined by dividing the ground slope in percent into the figure "10." In other words, if the slope of the furrow is 2 percent, the safe furrow stream is 10 ÷ 2, or 5 gallons per minute.

The control of the furrow stream is accomplished in many ways, the commonest of which is the syphon tube. Syphon tubes are made in sizes from ½ inch in diameter to as large as 10 inches, for the irrigation of close growing crops. It is now common practice to use several syphon tubes to supply a single furrow until the water has reached the end of the row. Then one or more tubes can be removed so that waste water from the end of the furrow is minimized.

A second method of flow control for furrows is by means of gated surface pipe. Gated pipe is usually made of light metals and comes in sizes from 3 inches in diameter to as large as 12 inches. A sliding gate is provided for each row. This permits careful regulation of the flow to each furrow. The pipe is easily portable and some farms of 160 acres are now irrigated without the use of any surface ditch.

For good rrigation practice, the water should reach the lower end of the row in one-fourth of the time required to irrigate the field. In other words, if it has been estimated that four hours are required to irrigate a field, then the water should reach the end of the rows in one hour. After this the stream should be reduced to minimize waste.

The sprinkler method of irrigation has been gaining greatly in popularity in late years. This is probably due to the invention and use of light portable pipe. Steel pipe was too heavy to be readily portable and too much work was required to move it. The pipe in modern sprinkler systems can be quickly moved from one location to another with a minimum of help.

There are on the market today several radically different types of sprinklers. The perforated pipe type consists of a pipe line in which a great number of small holes have been drilled. When water is applied

under low pressure, a large number of streams emerges to saturate the land area. The application rates of this type of sprinkler are rather high, the lowest being about ½ inch per hour while most of the systems apply about 1 inch per hour. It has met with favorable use for gardens and orchards.

The revolving head-type sprinkler is the most common in use today. Sprinkler heads have been developed to distribute water efficiently when the proper pressure is applied. Heads are usually spaced 40 feet apart on the line and the lines are moved in 60-foot intervals. This allows plenty of overlap and results in good distribution over the field surface.

The high-pressure-type sprinklers operate under pressures as high as 100 pounds per square inch. Some heads deliver as much as 450 gallons per minute each and cover a wide area. The latter type of sprinkler is used for tall crops, such as sugar cane or corn, where it is difficult to move pipe lines laterally.

The initial cost of sprinkler systems ordinarily ranges from $90 to $100 per acre. Operating costs vary, of course, with the type of system, the source of power, the availability of labor, and many other factors.

One of the greatest drawbacks of the sprinkler has to do with uneven distribution in windy weather. In some areas, labor costs are high and have retarded development.

The sprinkler system is particularly adapted to areas which cannot be irrigated by gravity, such as land which is sandy and has a high infiltration rate. Some areas have such rough topography and thin soils that land preparation is practically impossible. Such areas can better be irrigated by sprinkler than by other means.

Subirrigation requires specific surface and subsoil conditions to be successful. The areas where it can be successfully applied are few in the United States. Where the subsoil consists of porous material underlaid with an imperivous strata, it is possible to fill the subsoil with water and cause the water level to rise to the roots of the plants. Many thousands of acres are irrigated by this means in the San Luis Valley of Colorado and in some areas along the Platte River in Nebraska.

### Irrigation Potential in the United States

It is probable that every acre of land suitable for irrigation, and for which there is a water supply, will eventually be irrigated in this country. Irrigation practice is spreading very rapidly south and southeast. The state of Arkansas has nearly three-fourths of a million acres of irrigated land and Florida more than one-half million.

A survey of irrigation potential for the United States shows a possible 48,000,000 acres, as compared to the 25,785,000 now being irrigated, according to the 1950 census. The potential survey shows that, of the 48,000,000 acres, approximately 6,700,000 will be irrigated by sprinkler methods. It is my opinion that gravity irrigation methods can be applied in the humid regions much more than is being done at present. Gravity irrigation systems,

when properly designed and operated, are usually much cheaper in initial cost and operating cost than sprinkler systems. It is not a fact that sprinkler systems are always more economical in water or easier to operate than gravity systems. When this statement is made it usually indicates that the speaker is thinking of gravity systems long since outmoded and that he is not familiar with new gravity irrigation methods. I have looked at thousands of acres of land in Arkansas, Louisiana and other southeastern states which can be gravity-irrigated without difficulty.

It would seem to the author that good sense should be applied to irrigation practice, as in all other successful ventures. A careful appraisal should be made of the land to be irrigated, the water supply, crops to be grown, and even the man who is to do the irrigating. Then a system should be designed which will do the job most efficiently whether it be by sprinkler or gravity. It is unfortunate that in too many cases the designers of irrigation systems are not at all familiar with some of the new developments in land preparation in gravity methods of water application.

# Equipment for Beet Seed Treating

L. A. KLOOR[1]

During the past two decades, general acceptance by California sugar beet growers of the value of planting treated beet seed appeared to be more immediate and forthright than did processors' ability to acquire efficient equipment and develop standardized techniques of treatment to meet the demand for such treated seed.

The mandatory clause in the processor's sugar beet purchase contract which obligates the grower to acquire and plant sugar beet seed supplied by the processor is not a unilateral agreement. It certainly imposes upon the processor the moral responsibility for supplying the grower with the best seed obtainable, with every consideration given to all of the factors in seed production and processing which pertain to securing satisfactory seedling stands and high sugar production per acre at economical cost levels. The establishment of better stands of beets from treated seed has been proven and the acceptance of this means of obtaining such results by the grower emphasizes the obligation of the processor to supply treated sugar beet seed when it is demanded. Progressive processors have recognized this obligation and have done something about it.

With refinements in the processing of sugar beet seed during the past few years has come the trend toward lighter seeding rates. More recently, with the advent of and progress in mechanical thinning has come the planting technique of precisely spacing processed seeds one inch apart in the row. These trends have in mind the accomplishment of a single purpose—the emergence of a higher rate of evenly spaced, non-competitive, single seedlings. The importance of preventing the pre-emergence or post-emergence mortality of seedlings from any cause under these planting conditions cannot be exaggerated.

We are currently at the threshold of the production of monogerm sugar beet seed for commercial plantings. Precise planting of minimum quantities of this seed will be the obvious procedure. Here again preventive measures will have to be taken to insure against seedling losses from seed-borne and soil organisms or predators by means of seed treatment.

The apparent cautious attitude of processors towards seed treatment during the late thirties was justified. The general concept of the value of seed treatment was not new but the formulations of usable fungicides for the control of specific seedling diseases were not proven and efficient equipment for the proper application of these fungicides to seeds was non-existent. In some preliminary trials with some treating materials the delay in the emergence of and injury to the seed was severe enough to offset any possible advantages which might have resulted from the treatment. Another deterrent was the reluctance of individuals to handle some of our early treating materials since they were odious and poisonous. A further com-

[1] Research Agriculturist, Holly Sugar Corporation, Stockton, California.

plication arose when seed damage resulted from treating materials when applied too far in advance of the date of planting and the treated seed had to be stored.

Due in great measure to the untiring efforts of plant pathologists, fungicide manufacturers and beet sugar processors, many of the uncertainties which thwarted early efforts to introduce a safe and effective beet seed treating program have been surmounted. In this phase of sugar beet agriculture, the processor now finds himself in the position of having to keep abreast with new treating techniques and to make use of the most effective materials to satisfy his grower clientele. This is a healthy condition and in the long run can be conducive only to further improvement in the kind of treating we accomplish. A brief review of past and present methods of applying seed treating materials will show that we have made much progress. On the other hand, an objective survey indicates that some of our current methods of applying treating materials to sugar beet seeds are inefficient and could be the basic cause of failure of the fungicide to always give adequate protection.

## Treating Methods

The generally accepted methods of applying fungicides and insecticides to sugar beet seeds are these: 1. as a dry dust or powder; 2. as a water-fixed dust; 3. as a slurry, and 4. as a spray.

### Dry Dust Treating Equipment

In the first mentioned method, a dry dust formulation of the seed protectant is added to a batch of seed. The seed is weighed, placed in a rotary drum and the required quantity of fungicide added thereto. The seed is agitated for several minutes, or, at least until it appears that the seeds have been coated with fungicide dust. Many hundreds of pounds of sugar beet seed have been treated by California growers with an end-over-end rotary drum treater. This type of equipment is now outmoded. The procedure was slow, wasteful and undependable.

When processors first undertook to treat commercial quantities of seed, they purchased, or constructed, rotary dust treaters for the purpose. This type of treating equipment consisted essentially of a horizontally placed rotary cylinder into one end of which a controlled flow of seed was fed. A metering device fed the fungicide at a regulated rate into the same end of the cylinder. Proper treatment of the seeds was dependent upon the maintenance of a uniform flow of seed, the metering of the proper proportion of fungicide dust, and the thorough mixing of seed and dust as they traversed the length of the rotating cylinder. An arrangement of suction ducts at the sacking end of the cylinder permitted the removal of free dust by means of an exhaust fan. The treater was electric motor driven.

While this type of treater had ample capacity to meet the demand at the time for treated seed and gave fairly good results, it was frequently subject to quantitative inaccuracies in the mechanical measurement of the fungicide. Regardless of the type of metering device, troubles were con-

stantly encountered with this part of the treater. Today, campacting or channeling of dust in the feed hopper, which caused much of the trouble, would be eliminated by the use of a vibrator feed. Several excellent makes of these are currently manufactured.

In spite of every precaution and mechanical means to prevent it, the atmosphere around the treater became laden with fungicide dust particles and obnoxious fumes. Labor became disgruntled and, understandably, obstinate about working under these conditions. Also, this method of treating seed with what we considered an improved rotary type of applicator did not lessen the amount of fungicide which was wasted due to non-adherence to the seed coat. At this time there are no dry dust treaters being used by any processor in California for the treatment of sugar beet seed, and, so far as we know, none will be used for beet seed treatment in the future.

**Dust-Fixation Treating Equipment**

In this method of treating sugar beet seed, a wettable powder formulation of the fungicide is added to the seeds. The fine particles of the fungicide which adhere to the seed coat are "set" by praying the dusted seeds with a fine mist of water. To promote better adherence, a soluble sticker is sometimes added to the spray water.

The Clute treater embodies this principle of applying fungicides to beet seeds. A treater of this type is currently being used by a California processor. Briefly described, it consists of two horizontally mounted cylinders which compose a feed chamber and a mixing chamber, respectively. The smaller of the two cylinders (the feed chamber) contains a scroll which feeds seed and fungicide into the front end of the larger cylinder (the mixing chamber). This mixing chamber contains a broken scroll which tends to mingle seeds and fungicide as the mass is being conveyed to the discharge, or sacking, end of the chamber. Into one side of the mixing chamber, at a location approximately halfway between points of entry and discharge of this chamber, a fine spray of water is introduced to wet down and "set" the fungicide to the seed coat. Flat pattern 50-degree spray nozzles which deliver varying volumes of water at various controlled pressures are supplied by the manufacturer. By means of these calibrated nozzles the amount of moisture added can be controlled within tolerable limits. Fungicide and seed hoppers are mounted upon the feed chamber. Conventional auger-type feeds actuate and control the flow of the fungicide and seed. An electric vibrator is mounted on the fungicide hopper to minimize bridging-over or channeling. The entire treater is simply constructed and is built into a single compact unit. It is powered by a small electric motor. Satisfactory coverage of seeds at the treating rate of 900 pounds per hour gave adequate protection of seedlings against damping-off organisms. Caking of treating materials on the walls of the mixing chamber and the agitator paddles pose a cleaning problem.

**Slurry Treating Equipment**

In the slurry treatment of sugar beet seed, the wettable powder formulation of the fungicide is made up into a dense aqueous suspension

which is added to the seed mass. Seed surface coverage is accomplished by means of a weir which spreads a struck-measure volume of slurry over a weighed volume of seed. This is followed by thorough mixing as the seed mass is moved through a mixing chamber towards the sacking-off end of the treater.

While there are many slurry treaters being used in California for the treatment of various kinds of crop seeds, this type of treater has not been used by processors for the treatment of commercial quantities of sugar beet seed. The method is a vast improvement over any form of dry dust treatment for it gives seed protection comparable with that given by good dry dust treatment without the disadvantages previously enumerated.

Both the Caulkins and the Gustafson slurry treaters are well designed, compact, electric motor driven units. They are small and occupy a floor space measuring approximately 5 x 5 feet. Treating capacity is more than ample to meet the requirements of the average beet seed processing plant.

The Gustafson treater consists, essentially, of a seed-metering hopper, a slurry tank, a set of slurry measuring cups, a continuous flow pump and a mixing chamber. Seed which is to be treated is gravity-fed into the metering hopper of the treater. A counter-weighted tilting pan measures the seed and discharges its contents into the maxing chamber. Slurry is fed to the seed by the measuring cups which travel on an endless chain through the slurry tank contents. They fill and deliver a measured amount to the seed as it enters the mixing chamber.

These two actions are synchronized so that each time a pan of seed is discharged into the mixing chamber a measuring cup is brought up and its slurry contents discharged upon the seed. The movement of the measuring cups on the endless chain is actuated by the movement of the tilting seed pan each time a load is dumped. The slurry tank is quipped with an agitator. A circulating pump maintains a continuous flow of slurry through a small pipe directed into the measuring cup, thus effectively washing each cup after its discharge cycle. This prevents the gradual coating of the inner walls of the measuring cup with fungicide, the occurrence of which will result in the progressive error of measurement of slurry and undertreatment of seed. The unit is easy to clean. Operators using slurry machines for the treatment of delinted cotton reed report good results and negligible operational difficulties.

### Spray Treating Equipment

In the case of the spray method of applying fungicides to sugar beet seeds, the treating material is made up as an aqueous suspension and is sprayed on the seed mass as it is being agitated in a revolving drum. This method more completely eliminates dustiness and more nearly accomplishes uniformity of coverage with the treating materials than any other method devised for the treating of commercial quantities of sugar beet seed.

---

[2] Numbers in parentheses refer to literature cited.

There are two types of spray treaters in use at the present time. A semi-automatic batch spray treater designed in 1947 has been used by a California processor at two factory locations for several years. Several million pounds of sugar beet seed have been successfully treated with the equipment with very few changes in its original design. This type of spray treater was engineered by Armer (1)[2] who has explained its construction and principle of operation in a past publication (1948) of the Proceedings of the Society.

Another type of spray treater was designed in 1949 by Kepner and Leach (2). This treater is the continuous spray type. The first commercial model of this treater has been used by a processor since 1949 to meet the seasonal requirements of growers for processed treated seed. Several million pounds of sugar beet seed have been double treated with fungicide and insecticide with this equipment since its installation. The design, principle of operation and preliminary testing of the continuous spray-type treater have been described in detail by Kepner and Leach in the 1950 Proceedings of the Society. Its commercial operation has been fully described by the author in this same publication (3). There are five spray-type seed treaters being used for sugar beet seed in California. The purchase of the sixth by a processor is imminent. When this takes place, all processors in the state will be using spray-type treaters.

A very useful and efficient piece of supplementary equipment for a well planned and operated treating plant using spray-type equipment is the air-lift elevator. This type of elevator, used in connection with spray-type treaters for the transfer of untreated and treated seed, has many advantages over the conventional bucket elevator. Some of these advantages are:

1. less risk of mechanical damage to the seed; 2. additional cleaning during the transfer; 3. complete removal of any cork or fungicide dust which flakes off because of friction between seeds; 4. a minimum of moving parts; 5. self-cleaning, and 6. the beneficial drying action on seeds which have received moisture in the process of being treated. This type of elevator is easily installed and its operation is simplicity itself.

## Summary

The planting of treated sugar beet seed by California growers has become standard practice in all of the production areas of the state. This accomplishment was no sudden development, but rather the result of research and hard work extended over a period of 20 years.

The transition from dry dust treating with its attendant waste and operational difficulties to less obnoxious methods of treating sugar beet seed was a gradual process and came with the development of slurry and spray treating equipment.

Dust fixation and slurry treating equipment have alleviated the problem of dustiness but have not given the complete uniformity of seed coverage

obtained by the use of spray treating equipment. Uniformity of coverage becomes increasingly important when minimum rates of planting are made in contemplation of mechanically thinning the beet crop.

Spray-type treating equipment has supplanted other types in California principally because of its effective, uniform application of treating materials.

## Literature Cited

(1) ARMER, AUSTIN.
1948. A mechanical spray treater for sugar beet seed. Proc. Amer. Soc. Sugar Beet Tech. pp. 108-113.

(2) KEPNER, L. A. and LEACH, L. D.
1950. A continuous spray-type seed treater. Proc. Amer. Soc. Sugar Beet Tech. pp. 54-60.

(3) KLOOR, L. A.
1950. Experiences in the practical use of a continuous spray treater. Proc. Amer. Soc. Sugar Beet Tech. pp. 61-68.

# Seed Treating Machinery

GEORGE E. WALTERS[1]

For a number of years the beet sugar industry has been aware of the need to protect beet seed with a fungicide before issuing the seed to growers.

This paper will discuss three different types of seed treaters the Great Western Sugar Company has experimented with in the past three years. Before this time all of our seed treating has been done with a Calkins dry treater. Treating has not been satisfactory because the materials generally used were a hazard to the men operating the treater, and the machines do not meter small quantities of fungicide efficiently without a carrying agent. Also, in the dry-type treating method, it has been found that the fungicide would not stick to the seed sufficiently, and some material would settle to the bottom of the seed bags.

In our area, beet seed is treated with several fungicides, namely: Arasan, Arasan SF-X, improved Ceresan M, Phygon and Manzate. Also fume phosphate, Lindane and Heptachlor are used. For a treater to operate efficiently for our purposes, it should handle any of the above fungicides as well as commercial fertilizers and insecticides. This presents a problem because these materials comprise both the dry powder type and the wettable powder type. Further, a perfect treater should handle the liquid fungicides as well.

The three treaters to be discussed are:

1. The Clute wet treater made by the Clute Manufacturing Company of Rocky Ford, Colorado.

2. The Gustafson slurry treater made by the Ben Gustafson & Son Manufacturing Company, Moorhead, Minnesota.

3. The Kromer treater made by the O. W. Kromer Company, Minneapolis, Minnesota, and developed by the Green Giant people at LeSeuer, Minnesota.

## The Clute Treater

The Clute treater is a relatively small machine, comprising a double hopper for dry powder fungicide, a metering scroll for the fungicide, a beet seed hopper, two mixing chambers, spray nozzle, drives, and a 1/3 H. P. motor.

In the Clute system, the fungicide hoppers are equipped with syntron vibrators to keep the fungicide loose and even flowing. The fungicide is metered from the hoppers continuously with a small scroll and it contacts the beet seed in the first mixing chamber. The mixing chamber is a 6-inch diameter tube with a broken scroll moving the seed and fungicide to the end opposite the seed entry. Here the mixture drops down to another mixing chamber 7 inches in diameter and much the same as the first. After

[1] George E. Walters, Agricultural Engineer, the Great Western Sugar Company, Denver, Colorado.

the dry material and seed have been thoroughly mixed, the seed is sprayed with water or other solution to bind the fungicide to the seed. The spray is operated on 15 to 40 pounds pressure, and the amount of material used can be varied by the size of spray nozzle used. Among this machine's favorable points are its smallness, its simplicity, and the small amount of power required to operate it.

There are two apparent disadvantages with this machine. One is the machine's ability to handle only the dry type fungicides and insecticides. The other is the way the spray is used to set the fungicide to the seed. The spray nozzle is mounted on the side of the 7-inch diameter lower mixing chamber, and this does not allow the spray to contact all of the seed evenly. It was recommended by the manufacturer that we use an airlift to remove excess moisture that is added with the spray nozzle. The airlift will remove most of the moisture, but all also remove a relatively large portion of the fungicide. We tried changing the quantity of moisture added to correct this situation, but were unable to reduce the loss materially.

### The Gustafson Treater

The Gustafson slurry seed treater is a batch-type treater. A weighing dump that is part of the machine weighs the seed and drops it into a mixing chamber. A batch or bucket of slurry is dumped into the chamber each time the weighing hopper is dumped. Instead of the slurry being dumped directly on the seed, it runs through a hopper which spreads the slurry more evenly on the seed. Wettable powder or the liquid type fungicide is used in the treater and is kept in suspension by an agitator which operates while the machine is running. The treater is small and operates simply and smoothly. It requires a ⅓ H. P. motor to drive it.

Some of the good points of the Gustafson machine are its compactness, its simplicity, and the small amount of power required to operate the treater. Also, the wettable powder or the liquid fungicides are much safer for the operating personnel to handle because of freedom from toxic dust.

A disadvantage of this machine for use with beet seed is the manner in which the slurry contacts the seed. Because of the absorbent qualities of beet seed, the slurry will be absorbed by only the seed it contacts directly. In this machine the mixing chamber is small and the slurry will not contact all of the seed.

The Gustafson people are developing a new type slurry treater that has some very desirable features. In this treater the slurry drops on a disc spinning at a high speed to atomize the slurry. The atomized slurry then contacts the seed. From what we have learned of this machine, it should have some definite improvements for handling beet seed.

### The Kromer Treater

The Kromer treater (developed by the Green Giant people) is a large machine that will handle both dry and wettable type fungicides. It is also possible that the liquid type fungicides may be used in this machine much

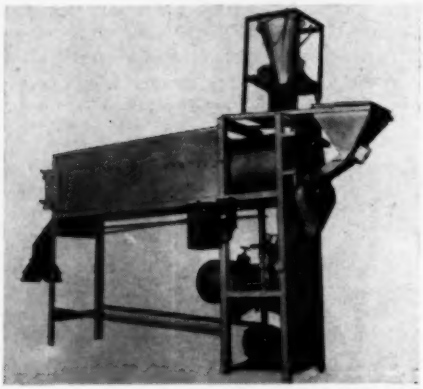

**Figure 1.—The Kromer uniform coat seed teater.**

the same as in the (1)[2] Kepner and Leach treater. The Kromer treater consists of a double funnel fungicide hopper, mixing chamber, seed feeding hopper, a small centrifugal pump, water or set tank, a small air compressor, and a three-H. P. motor with drives.

The double funnel fungicide hopper forms a well controlled metering device. The inside hopper is to control the depth of the fungicide in the outside hopper. The inside hopper has an agitator tending to push the fungicide upward to keep it from packing. The outside hopper has a syntron vibrator on it to keep the fungicide loose and free flowing. The outside hopper feeds into an adjustable vibrating metering trough or hopper, to keep the flow of the fungicide constant. The fungicide then enters the upper end of the mixing chamber. A blast of air from a small air compressor mounted on the machine is directed on the fungicide as it enters the chamber to produce a fog. The treater also has a water spray pipe and a seed chute entering the upper end of the mixing chamber and operates at 40 pounds pressure. The mixing chamber is 2 feet in diameter and 10 feet long with ½-inch half round bars spaced at 90 degrees around the inside of the chamber to keep the seed turning over and over. Located on the lower end of the mixing chamber is an inspection glass and light so the operator can watch the operation. Because of the abrasiveness of the beet seed, none of the fungicide sticks to the sides of the chamber; however, there is a definite relationship between the seed, fungicide, and moisture for the machine to operate properly.

The principal advantage of this machine is the complete coverage of fungicide on the seed. This coverage is no doubt due to the large mixing chamber and the time it is in the tube.

Disadvantages are its size and the seals that have to be made at the ends of the mixing chamber, as the ends are stationary and the chamber revolves.

---

[2] Numbers in parentheses refer to literature cited.

Treating tests using Arasan, Arasan SF-X and Manzate were run on the three machines. Norman Gerhold[3] at Colorado A and M College is conducting mold tests on the treated seed. The tests were not completed in time for this meeting, but they will be available later.

In conclusion, I believe that our treaters of the future will have to handle the wettable powder and liquid type fungicides with sticking agents. The new fungicides will no doubt be of these types. The principal features of these new machines will include a spray, a churning of the seed, and a long enough time in the mixing chamber to properly attach the material.

## Literature Cited

(1) KEPNER, R. A., and LEACH, L. D.
1950. A continuous spray type seed treater, Proc. Am. Soc. Sugar Beet Tech. pp. 54.

[3] N. R. Gerhold, Asst. Plant Pathologist, Colorado A and M College Experiment Station.

# Processing and Testing of Monogerm Seed[1]

(A panel discussion composed of L. A. KLOOR, Moderator, GEORGE E. WALTERS, G. E. RUSH, CHARLES PRICE AND AUSTIN ARMER.)[2]

**Processing and Plantitng**—Holly Sugar Corporation[3]

Two monogerm hybrid seed quantities of sufficient size for commercial testing were sent to Stockton, California, for processing. This quantity represented a sizeable portion of the total monogerm seed available for purposes other than breeding.

Briefly, little or no difficulty was encountered in processing either of the two varieties of monogerm seed. It was concluded that this type of seed could be successfully processed and average recovery attained. The characteristic flat shape of monogerm seed did not present any unsurmountable problem either in processing or planting.

Planting was made in two commercial fields with two types of commercial planters, a John Deere and an International. A very minor modification was made on the John Deere in order to adapt the plates to the flat character of the processed monogerm seed.

Each of the two plantings were made in fields with multigerm beets on either side. One planting was made on the Holly ranch at Tracy, California on April 25. Two pounds of seed per acre were planted at a speed of 2½ miles per hour. These beets were not thinned, a hoe was not permitted in the field until weeding time. This field was harvested after 201 days of growth and produced 20.23 net tons per acre, with an average sucrose percentage of 15.05 and a gross yield of sugar of 6,151 pounds per acre. This compared favorably with the multigerm variety in the same field, which had 60 additional growing days. The commercial field yielded 29.10 tons per acre.

A record planting at Tracy, California, was made one month later, using the unbelievably small amount of 1.029 pounds per acre. Seed was planted in 30-inch rows at a spacing of approximately three inches apart. An excellent stand was obtained which, at thinning time of the commercial multigerm, gave 205 beets per 100 feet of row. The only doubles occurred where the drill plate apparently accepted two seeds in a plate cell.

In this second planting, both the monogerm and multigerm were of identical age at harvest. The monogerm planting yielded 18.10 tons per acre with 16.14% sucrose and gross sugar per acre of 5,842 pounds. The commercial planting yielded 18.06 tons per acre, 16.81% sucrose and a gross sugar of 6,072 pounds per acre.

---

[1] Results here presented are of preliminary nature. Tests of monogerm seed processing, planting and thinning were conducted to answer questions of a nature necessary to the continuation of the monogerm plant breeding program.

[2] Comments by George Walters appear as a separate paper. Data presented by G. E. Rush was not made available for publication.

[3] Presented by L. A. Kloor.

Since the germination percentage of monogerm can be raised through processing, weight per bushel increased, and processing accomplished with standard decorticating and processing equipment, it can be concluded as follows: (1) Monogerm seed can be processed successfully, (2) Good yield of processed seed can be obtained from whole seed and (3) Comparable beet yields can be obtained from monogerm seed.

**Photographic Inspection of Monogerm Seed**—Spreckels Sugar Company[4]

By methods of "trick photography" close inspection of processed monogerm seed has been recorded on photographic film. By use of mirrors, the top view and side view were photographed simultaneously through a screen 1/64ths of an inch apart. By this method, the top and side of a seed can be observed and compared.

Comparisons were made between the original recleaned seeds and decorticated seed. Before decortication, some evidence of biscuit-shaped flatness can be observed, particularly in the larger seed. The smaller seeds show a more or less roundness of spherical nature. A very definite flattening is observed in the silhouette of the processed seed.

Since this flat character of the seed is expected to give difficulty in the mechanical handling of seed in drills, pelleting has been suggested as a means of curing this ill. Unfortunately and in spite of the spherical shape imparted to the seed through pelleting, pelleting has not had much success in sugar beets. It is expected that the flat seed character can be eliminated through the plant breeding programs. With this aid of the plant breeders and a little caution in using this seed in planters, no particular troubles are expected from this flat characteristic.

Some concern is being shown toward Monogerm's natural small size. If this characteristic persists, some planter changes will be necessary to accommodate smaller seed sizes. Perhaps it is too early to be concerned over these factors since a few of our earlier concerns have been proved to be needless.

**Planting Tests**—U. S. Department of Agriculture[5]

Test plantings with monogerm whole, monogerm processed, monogerm pelleted, U. S. 56 processed and U. S. 56 pelleted were made at Brawley, California, on September 24, 1953. These plantings were made in a characteristically rough seed bed, typical to the conditions of the Imperial Valley. Such conditions cause irregularity in seed depth, some are placed shallow, others deep. This planting was irrigated up in the normal manner on September 28.

It was observed that a better stand was obtained from the unpelleted seed than from the pelleted seed. The pelleted seed emergd slower than those which were not pelleted. The whole seed produced a large portion of doubles and some triples, more than likely caused by seeds "stacking up" in the cells of the drill.

---

[4] Presented by A. A. Armer.
[5] Presented by Charles Price.

Under greenhouse conditions, these same tests gave further results. Less of a delay between emergence of pelleted versus unpelleted seed than in the field was observed. The trays in the greenhouse were irrigated well which would lead us to believe that large quantities of water are necessary to make pelleted seed perform nearly as well as the bare.

In any case, a very definite increase in the number of single plants was noticed from monogerm seed. This was noticed regardless of the treatment the monogerm seed had received.

**Monogerm Field Trials**—Utah-Idaho Sugar Company[6]

During 1953, the Utah-Idaho Sugar Company conducted a total of 14 field trials comparing processed monogerm seed sized 8-10 and decorticated multigerm seed sized 8-10. In these trials, five pounds of seed were sent to each factory district with the request that they go into fields where farmers were drilling, empty two cans of the drill, place the monogerm seed in the two cans and make several rounds in the field. This gave us alternate 4-row strips of processed monogerm and decorticated multigerm seed, both of which had been processed and sized 8-10/64ths.

Satisfactory stands were obtained in all of these trials and it was evident that processed monogerm seeds sized the same size as the seed we are now using in the districts could be planted very satisfactorily with all of the improved drills now in operation in our various districts. Counts on these comparative strips showed 64% singles from the decorticated seed and 89.6% singles from monogerm seed.

This would indicate that when monogerm seed becomes available for commercial planting, it would prove to be advantageous in our spring mechanization program. It might be summed up b ysaying that we see no particular problems in the handling and planting of monogerm seed. We expect to be able to plant it with the same drills that are now in use and mechanically thin it with the same type of mechanical thinners which we are using at the present time.

[6] Presented by Bion Tolman.

# Field Stands Obtained from Plantings of Variously Processed Mono- and Multi-Germ Sugar Beet Seed

GEORGE E. WALTERS[1]

With mono-germ seed becoming more and more a reality there is much work to be done on processing the seed so it can be handled in our present drills. Also, there may be some change in thinning methods. In the past two years the Great Western Sugar Company has obtained some very interesting results with mono- and multi-germ seed, both bare and coated.

Table 1 gives results obtained in 1952 with our commercial segmented seed, bare and coated. In order to get an exact comparison, we took 300 pounds of our untreated commercial seed, mixed it thoroughly, and then took 100 pounds of this mixed seed to the Filtrol Corporation in California and had it coated. For the plantings, we used two Milton drill units with the correct size seed plates for use with the bare and coated seeds. The plantings were made in a four-state area: Montana, Wyoming, Nebraska and Colorado. Preference was not given to fertility, seed beds, etc., in making the plantings.

The seed was drilled on farms where the farmer was using a Milton drill on which our units could be attached. Two rounds were made in each field, making four rows of the coated seed and four rows of the bare seed. As you will note on the chart, the percent emergence of the coated seed was slightly above that of the bare seed. Also, a much better planting pattern was obtained with the coated seed, indicating that there was some shearing of the bare seed in the drill units.

Table 2 gives results of mono- and multi-germ plantings made on the Windsor Experimental Farm in 1953. These experiments were made to determine what advantages we can expect with mono-germ seed with respect to mechanical thinning. After the plantings and emergence counts were made we had some very adverse weather conditions (8 degrees above zero) and we began to doubt the value of the experiment. The emergence figures used in the chart are taken from the first counts before the storm; however, new counts had to be made prior to thinning. The results obtained in our thinning after the second counts were satisfactory. Of the five ways the seed was handled, the coated seed showed a distinct advantage over the bare seed in the number of singles obtained. This was probably due to cell fill on the drill at the time of planting. The Milton drill fitted with the proper size plates was used in the experiment.

Since the coated seed shows up so well in these tests, I think it would be proper to give a brief account of the coating process. The coating process is very time-consuming. The actual machine consists of a 60-inch diameter ball with an opening to admit the seed. It takes one man two to three hours to coat one 50-pound batch of seed. The operator will be busy adding the coating material and moisture. The coating is a dry powder and water is

[1] George E. Walters, Agricultural Engineer, the Great Western Sugar Company, Denver, Colorado.

**Table 1.—Comparison of Bare and Coated Seed Plantings in 1952[1]**

| Factory | Type of Soil | Condition of Seed Bed | Fall or Spring Plowed | Precip. 1st 2 wks. | Which Came Up First | % Emergence | |
|---|---|---|---|---|---|---|---|
| | | | | | | Bare | Coated |
| 1. Billings | Light | Good | Fall | .45" | Bare | 57 | 57.8 |
| 2. Billings | Sandy Loam | Fair | Fall | .15 snow | Bare | 50.5 | 53.6 |
| 3. Lovell | Silt Clay | Good | Fall | .15 | Same | 53.4 | 74.4 |
| 4. Wheatland | | | | 0 | Same | 33.5 | 35.8 |
| 5. Gearing | Sandy Loam | Fair | Fall | .21 | Same | 16.5 | 15.8 |
| 6. Scottsbluff | Sandy | Fair | Spring | .19 | Same | 30 | 32.2 |
| 7. Lyman | Light Silt | Good | Spring | 0 | Bare | 26.5 | 32.5 |
| 8. Mitchell | Sandy Loam | Fair | Spring | .09 | Bare | 21.2 | 28.7 |
| 9. Longmont | Clay Loam | Fair | Spring | .45 | Same | 22.3 | 25.4 |
| 10. Loveland | Clay | Fair | Fall | | Bare | | |
| 11. Fort Collins | Clay Loam | Fair | Fall | 1.02 | Same | 31 | 45.2 |
| 12. Sterling | Sandy Loam | Good | Spring | 3.6 | Same | 19.2 | 10.3 |
| 13. Longmont Experiment Station | | | | | | 15.96 | 55.31 |
| 14. Ovid | Clay Loam | Fair | Spring | 1.24 | Bare | 20.9 | 8.9 |
| Average Percent Emergence, All Counts | | | | | | 33.38 | 35.07 |

[1] This table based on: Bare Seed—57,449.8 germs per pound of seed; Coated Seed—8,553.6 germs per pound of seed; Bare Seed—41,580 seed balls per pound of seed; Coated Seed—4,760 seed balls per pound of seed.

**Table 2.—Results of Single Germ Plantings Made at Windsor in 1953[1]**

| Type Seed | Seed Description | | | | Germination (Average 16 Counts) | | | | | | Thinned Stand | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Seed Balls /lb. | Germs /lb. | % Germ. | % Sngls | % Emergence | Sngls | Dbls | Trpls | Total Beets /100" | Total Inches /100" | Per 100" Sngls | Dbls | Trpls | Per Beet Hills | 100' Total Beets |
| Tehachapi Mono-Germ Decorticated, Bare | 67,400 | 44,653 | 66.25 | 99.62 | 63.6 | 32.5 | 11.0 | 2.25 | 61.0 | 45.75 | 9.0 | .95 | 0 | 119.4 | 128.0 |
| Tehachapi Mono-Germ Decorticated, Coated, Small Size | 9,560 | 7,361 | 77.00 | | 75.7 | 26.2 | 2.5 | .05 | 32.5 | 28.75 | 7.6 | .2 | 0 | 93.6 | 96.0 |
| Tehachapi Mono-Germ Segmented, Bare | 62,360 | 41,937 | 67.25 | 98.88 | 63.4 | 28.5 | 6.25 | .625 | 42.8 | 35.05 | 8.1 | .25 | 0 | 100.2 | 104.4 |
| Commercial Segmented, Bare | 41,580 | 57,450 | 86.25 | 46.2 | 57.7 | 21.8 | 11.05 | 4.70 | 59.5 | 37.55 | 8.8 | 1.5 | .2 | 126.0 | 148.8 |
| Utah-Idaho Mono-Germ, Bare | 40,520 | 36,265 | 89.5 | 99.0 | 55.8 | 22.3 | 7.1 | .5 | 35.75 | 29.9 | 8.2 | .7 | 0 | 106.8 | 118.8 |
| Tehachapi Mono-Germ Decorticated, Coated, Large Size | 8,800 | 6,949 | 78.25 | | 66.2 | 21.5 | 1.8 | 0 | 24.75 | 23.3 | 8.7 | .25 | 0 | 107.4 | 109.85 |
| Commercial Segmented, Coated | 5,760 | 8,554 | 88.50 | 42.7 | 53.2 | 17.0 | 9.1 | 1.5 | 38.5 | 27.6 | 7.8 | .7 | .05 | 102.7 | 114.6 |

[1] Date of Planting—April 6, 1953.

introduced to enable the coating to form on the seed. Several times during the process the seed has to be screened to separate the seeds which have reached the size desired. The sizing screen is a long cylindrical type with four sizes of mesh. The axis of the cylinder is at an angle to the horizontal so that the seed will move from one end to the other. The first screen has an 8/64 inch mesh, number 2—10/64 inch mesh, number 3—12/64 inch mesh, and number 4—14/64 inch mesh. This will allow different sizes of seed to be screened off. Undersize seed is returned to the coating machine. The seed of desired size is dried for six hours in racks of drying trays. The trays are constructed with screen bottoms to allow warmed air to pass through the seed.

It would be practically impossible for all of any one company's beet seed to be treated in this manner because of the space required for the coating machinery and the time involved in the actual coating process.

Fred Burgresser has been working on a continuous-type coating machine, and if it proves satisfactory it would then be possible for a sugar company to process all of its seed. If coating of the mono-germ seed is accepted, we should expect a much higher percent of singles and a more uniform stand, using our present-day drills.

# AUTHOR INDEX


Page

ARMER, AUSTIN
Influence of machine harvest on receiving facilities ..... 324
Processing and testing of monogerm seed ..... 376

BAIRD, BRUCE L.
The use of chemical additives to control soil crusting and increase emergence of sugar beet seedlings ..... 136

BARDIN, ROY
An alternaria leaf spot of the sugar beets ..... 241

BENNETT, C. W.
Effect of virus yellows on the yield and sucrose percentage of the sugar beet at Salinas, California, in 1952 ..... 215
Observation and studies of virus yellows of sugar beet in California ..... 230
Effect of virus yellows on yield and sucrose content of sugar beet in tests at Riverside, California ..... 236

BOCKSTAHLER, H. W.
Stand and yield of sugar beets, and weed populations as affected by: broadcast fertilization, mechanical thinning, application of herbicides and their interactions ..... 95

BONNEMANN, JOSEPH J.
The use of chemical additives to control soil crusting and increase emergence of sugar beet seedlings ..... 136

BRANDT, R. W.
End dump arrangements on old and new receiving equipment ..... 333

BUCHHOLTZ, W. F.
Correlation between sugar beet crop losses and greenhouse determinations of soil infestation by Aphanomyces cochlioides ..... 252

BURTCH, LAUREN
Response of yield-type versus sugar-type sugar beet varieties to soil nitrogen levels and time of harvest ..... 64
The influence of Maleic Hydrazide on bolting and yield of overwintered sugar beets in California ..... 176

CARLSON, CARL W.
The effect of fertilizer treatments upon yield and sugar content of sugar beets at Garden City, Kansas ..... 42

COOL, L. R.
Sugar beet storage problems ..... 353

COONS, G. H.
Results of an experiment in Colorado to appraise effects of virus yellows in sugar beet ..... 219

**AUTHOR INDEX** (Cont.) Page

CORMANY, C. E.
Cooperative Research ... 3
A study of the effect of magnesium sulfate on yield ... 32
Pre-emergence applications of a combination of TCA and Endothal show promise for control of grassy and broadleaf weeds in sugar beets ... 135

COSTA, A. S.
Effect of virus yellows on the yield and sucrose percentage of the sugar beet at Salinas, California in 1952 ... 215
Observation and studies of virus yellows of sugar beet in California ... 230

DANIELS, LESLIE B.
Results of an experiment in Colorado to appraise effects of virus yellows in sugar beet ... 219

DEMING, G. W.
Estimate of space occupied proposed as a measure of sugar beet stands 151

DORST, HOWARD E.
Beet leafhopper outlook statements ... 201

DOUGLASS, J. R.
Outbreaks of beet leafhoppers north and east of the permanent breeding areas ... 185

DRAHER, H. L.
An improved method of applying fertilizer to sugar beets ... 285

DUBETZ, S.
The fertility balance in a ten-year sugar beet rotation after forty-two years of cropping ... 81

ECKROTH, E. G.
Results with IPC spraying in Eastern Montana ... 135
Thinning trials in Eastern Montana ... 302

FIFE, DON C.
Sugar beet planting date studies in Imperial Valley, California ... 164

FIFE, J. M.
Chromatography as a method of attack on the problem of chemical nature of resistance of sugar beets to curly top ... 207

FINK, H. C.
Correlation between sugar beet crop losses and greenhouse determinations of soil infestation by Aphanomyces cochlioides ... 252

FRAKES, M. G.
Minimum seed bed preparation ... 281
An improved method of applying fertilizer to sugar beets ... 285

**AUTHOR INDEX** (Cont.) Page

FRENCH, GEORGE W.
Stand and yield of sugar beets, and weed populations as affected by: broadcast fertilization, mechanical thinning, application of herbicides and their interactions ... 95
A dynomometer for determination of the power requirements of a sugar beet thinner ... 313

GASKILL, JOHN O.
Results of an experiment in Colorado to appraise effects to virus yellows in sugar beet ... 219
A comparison of several methods of testing sugar beet strains and individual roots for resistance to storage pathogens ... 264

GIDDINGS, N. J.
Curly top moves east ... 194
Relative curly-top resistance of sugar beet varieties in the seedling stage ... 197
Sugar beet virus yellows influences subsequent curly top infection ... 212

GILLESPIE, GLENN E.
Effect of virus yellows on yield and sucrose content of sugar beet in tests at Riverside, California ... 236

GRIGSBY, BUFORD H.
Stand and yield of sugar beets, and weed populations as affected by: broadcast fertilization, mechanical thinning, application of herbicides and their interactions ... 95

HADDOCK, JAY L.
Irrigation and fertility studies on sugar beets at Logan, Utah ... 106

HALL, H. L.
Preliminary comparison of the effects of leguminous and non-leguminous green manures on sugar beet production ... 90

HAMMAN, R. E.
Endrin—a new insecticide for sugar beet webworm control ... 276

HANSEN, VAUGHN E.
Irrigation and fertility studies on sugar beets at Logan, Utah ... 106

HARRIS, LIONEL
Cropping and fertilization practices for the production of sugar beets in Western Nebraska ... 71

HASS, H. B.
What's new in sugar research? ... 15

HENDERSON, L. H.
Five years' experience in complete mechanical thinning of sugar beets 309

HENDERSON, M. C.
Status of spring mechanization in the Michigan area ... 299

HERRING, ROY B.
The effect of fertilizer treatments upon yield and sugar content of sugar beets at Garden City, Kansas ... 42

**AUTHOR INDEX** (Cont.) Page

HILLS, F. J.
The application of petiole analysis to sugar beet fertilization ... 48
Response of yield-type versus sugar-type sugar beet varieties to soil nitrogen levels and time of harvest ... 64
Preliminary comparison of the effects of leguminous and non-leguminous green manures on sugar beet production ... 90
The influence of Maleic Hydrazide on bolting and yield of overwintered sugar beets in California ... 176
Field trials with soil row treatment for the control of damping-off of sugar beets ... 260

HOGABOAM, G. J.
Stand and yield of sugar beets, and weed populations as affected by: broadcast fertilization, mechanical thinning, application of herbicides and their interactions ... 95

HOLMBERG, D. M.
Response of yield-type versus sugar-type sugar beet varieties to soil nitrogen levels and time of harvest ... 64

HOLMES, L. J.
Problems connected with high beet populations ... 147
Relationship of screening to beet population ... 327

HOLST, E. M.
A study of the effect of magnesium sulfate on yield and sucrose content of sugar beets ... 32

HUNTER, ALBERT S.
Comparison of hand and machine thinning of sugar beets ... 161

JOHNSON, ART
Improved beet sample taking with new-design pan ... 340

JOHNSON, CHARLES R.
Comparative efficiency of rubber and steel Rienks screens ... 330

JOHNSON, R. E.
Adapting the Marbeet Midget beet harvester to experimental plot harvest ... 356

JOHNSON, RONALD C.
Mechanical thinning of sugar beets in the area served by the Utah-Idaho Sugar Company ... 306

KAY, CURZON
Problems connected with high beet populations ... 147
Relationship of screening to beet population ... 327

KIDDER, ERNEST H.
Progress report on irrigation experiment—Rader farm, Saginaw, Michigan ... 120

**AUTHOR INDEX** (Cont.) Page

KLOOR, L. A.
Equipment for beet seed treating ..... 366
Processing and testing of monogerm seed ..... 376

KRANTZ, B. A.
Response of sugar beets to nitrogen fertilizer in the Imperial Valley, California ..... 36
Sugar beet planting date studies in Imperial Valley, California ..... 164

LACKEY, C. F.
Histological changes produced by virus yellows in sugar beet leaves ..... 225

LARSON, W. E.
Effect of method of application of double superphosphate on the yield and phosphorus uptake by sugar beets ..... 25

LEACH, L. D.
Field trials with soil row treatment for the control of damping-off of sugar beets ..... 260

LEAVITT, F. H.
Anhydrous ammonia, the effect of time, rate and technique of its application in the production of sugar beets ..... 58

LOHMEIER, L. A.
Planting for machine thinning ..... 296

LYONS, TORREY
Field trials with soil row treatment for the control of damping-off of sugar beets ..... 260

MACKENZIE, A. J.
Response of sugar beets to nitrogen fertilizer in the Imperial Valley, California ..... 36

MALETIC, JOHN T.
Preventative weed control—methods and equipment ..... 291

MCFARLANE, J. S.
Effect of virus yellows on the yield and sucrose percentage of the sugar beet at Salinas, California, in 1952 ..... 215
An alternaria leaf spot of the sugar beets ..... 241

MILLER, W. MCNAB
Sugar beet irrigation experiments in Wyoming ..... 112

NELSON, R. T.
Grass control in sugar beets with the herbicides IPC, TCA and DCU 130
Endrin—a new insecticide for sugar beet webworm control ..... 276

NIXON, GEORGE W.
Harvesting equipment ..... 320

PARTRIDGE, JAY R.
Sugar beet irrigation experiments in Wyoming ..... 112

**AUTHOR INDEX** (Cont.)

Page

PENDLETON, R. A.
Cultural practices related to yields and germination of sugar beet seed ... 157

PETO, F. H.
Sugar losses caused by frost defoliation ... 171

PRICE, CHARLES
Sugar beet planting date studies in Imperial Valley, California ... 164
Effect of virus yellows on yield and sucrose content of sugar beet in tests at Riverside, California ... 236
Processing and testing of monogerm seed ... 376

REEVE, HAL B.
Progress report on irrigation experiment—Rader farm, Saginaw, Michigan ... 120

RHOADES, H. F.
Cropping and fertilization practices for the production of sugar beets in Western Nebraska ... 71

RICHARDS, ARCH W.
The use of chemical additives to control soil crusting and increase emergence of sugar beet seedlings ... 136

RIETBERG, H.
Experiences with sugarbeet on land flooded by the sea ... 168

RIRIE, D.
The application of petiole analysis to sugar beet fertilization ... 48
Preliminary comparison of the effects of leguminous and non-leguminous green manures on sugar beet production ... 90
The influence of Maleic Hydrazide on bolting and yield of overwintered sugar beets in California ... 176

RUSH, G. E.
Processing and testing of monogerm seed ... 376

SCHNEIDER, C. L.
Methods of inoculating sugar beets with Aphanomyces cochlioides drechs ... 247

SERRO, R. F.
Identification of some materials in root exudates of nematode (Heterodera Schachtii, Schmidt) host plants ... 271

SMITH, C. H.
Influence of Krilium soil conditioner on sugar content of beets ... 143

SNYDER, WILLIAM C.
An alternaria leaf spot of the sugar beets ... 241

STIER, R. L.
Anhydrous ammonia, the effect of time, rate and technique of its application in the production of sugar beets ... 58

STONE, J. G.
Basic beet piler design and its application to construction ... 344

**AUTHOR INDEX** (Cont.)

Page

SWIFT, E. L.
Conserving and handling beet tops ... 357

TANNER, J. C.
Effects of rotation on sugar beets in the Red River Valley ... 86

TOLMAN, BION
Mechanical thinning of sugar beets in the area served by the Utah-Idaho Sugar Company ... 306

TVEDTEN, H. A.
Spring mechanization in the Red River Valey—1953 ... 305

TYLER, CARROL
Sugar beet irrigation experiments in Wyoming ... 112

ULRICH, A.
The application of petiole analysis to sugar beet fertilization ... 48
Response of yield-type versus sugar-type sugar beet varieties to soil nitrogen levels and time of harvest ... 64

WALTERS, GEORGE E.
Seed treating machinery ... 372
Processing and testing of monogerm seed ... 376
Field stands obtained from plantings of variously processed mono- and multi-germ sugar beet seed ... 379

WARREN, L. E.
The control of annual grasses in sugar beets with Dalapon ... 124

WATSON, A. M.
Five years' experience in complete mechanical thinning of sugar beets 309
Five years' mechanical harvesting experience with completely machine thinned beets ... 318

WEISS, MARTIN G.
Patterns of cooperation in sugar beet research ... 7

WILKINSON, READ A.
Basic beet piler design and its application to construction ... 344

WILLIAMS, W. A.
Preliminary comparison of the effects of leguminous and non-leguminous green manures on sugar beet production ... 90

WOOD, IVAN D.
Irrigation of sugar beets ... 362

WOOD, R. R.
Identification of some materials in root exudates of nematode (Heterodera Schachtii, Schmidt) host plants ... 271

YEAGER, GLEN W.
Beet receiving equipment ... 337

YUNGEN, JOHN A.
Comparison of hand and machine thinning of sugar beets ... 161